FOOD RESEARCH INSTITUTE STUDIES

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FOOD RESEARCH INSTITUTE

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MERRILL K. BENNETT

A WORLD MAP OF FOODCROP CLIMATES*

This paper presents a map of world climates which, to students interested in study of the relationship of climate to world geographical distributions of major food crops and regional crop complexes, may perhaps prove more serviceable than do the various maps of world climates such as usually find a place in geographical atlases and textbooks on climatology. Those maps on the one hand aim at description of climates for its own sake, to portray how the face of the earth, especially its land surface, is apportioned among regions which may be said to differ one from the other in some sense involving average circumstances of both temperature and precipitation. On the other hand, conventional climatic maps subscribe to what Miller calls the "general principle that a satisfactory classification of climates must reflect the climatic control of vegetation; that climatic provinces must coincide as closely as possible with major [natural] vegetational regions of the globe" (*1*, p. 86). The maps here presented do not deal with descriptive differentiation of climates for its own sake but seek to differentiate climates according to their relative hospitality to production (unirrigated) of major food crops, and, this being the aim, major regions of natural vegetation play no part, unless it be accidental, in the differentiations among climates.

Principles of classification have been selected with a view to presenting a picture of world distribution of foodcrop climates that may be readily grasped because of the moderate number of resulting climates and the relatively few criteria of differentiation. The principles of classification will emerge sequentially in the discussion. Not all of the concepts of the differentiating boundaries are as firmly based as may be desired, and the location of bounding isolines are in many instances insecure by reason of conflict of authority, failure to examine the full world range of available meteorological data, or absolute paucity of such data in some parts of the world.

FOODCROP AND NON-FOODCROP CLIMATES

Common observation, together with accumulated knowledge of the quantities of heat (light taken for granted) and water required if a food crop is to mature seeds or cuttings permitting its own reproduction, certify to the existence on the earth of some climates too cold for cultivation of all food crops and of other cli-

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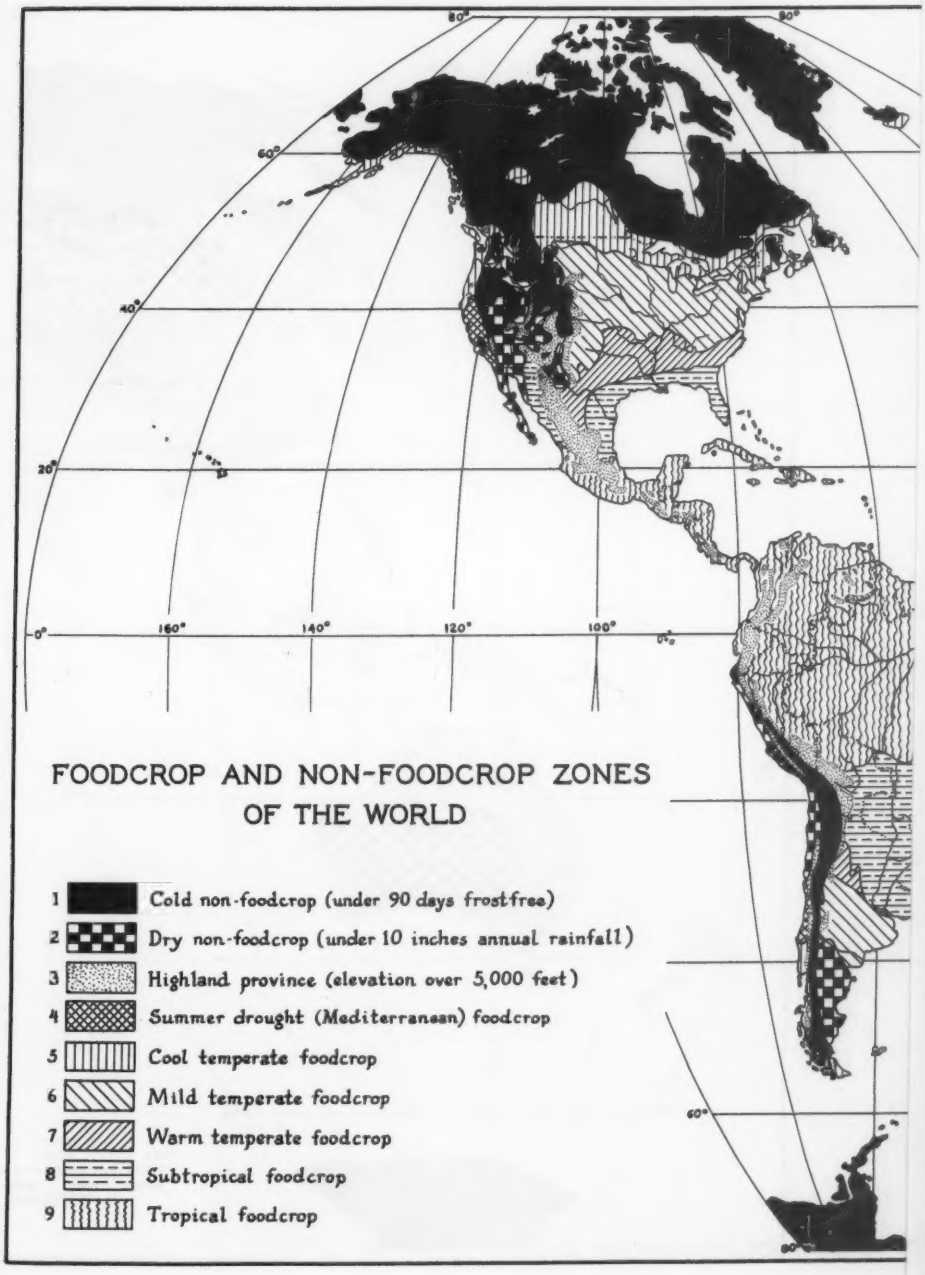
mates that are too dry, failing irrigation in some form. Extremely high rainfall in itself does not preclude cultivation of some known food crop, nor does extreme natural sun heat.

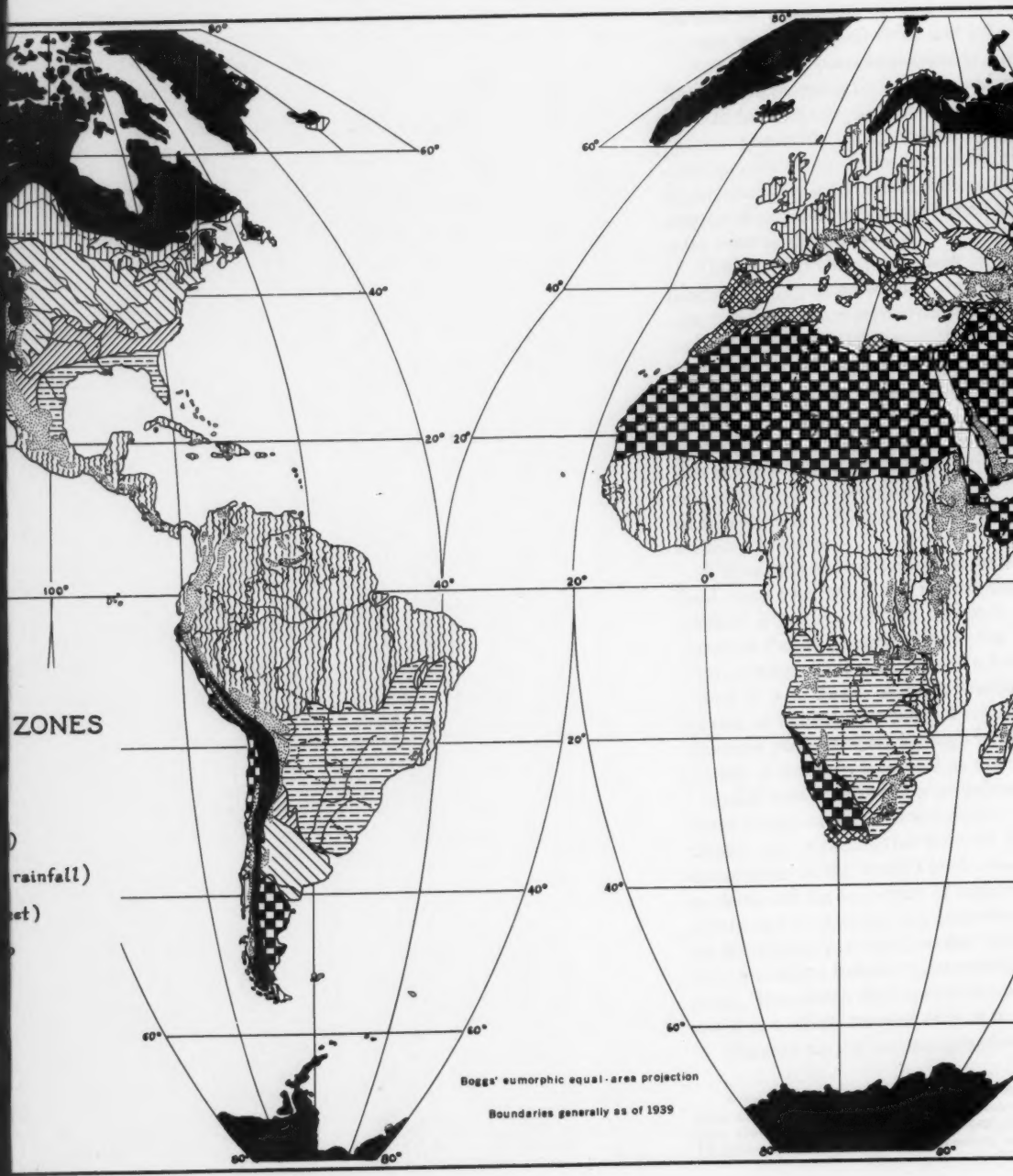
The initial problem in mapping foodcrop climates may therefore be taken as one of marking off areas of the world which are too cold for persisting cultivation of any major food crop. Some sort of an isoline is necessary to denote the boundary between regions which are and which are not too cold to permit substantially regular maturation of the materials of the plant's reproduction. We take as "major food crops" typically those which nowadays yield relatively the largest quantities of dry matter edible by man; they tend also to occupy large acreages though not in proportion to dry matter produced because of differences in yield per acre. A defensible catalog of major food crops includes but is not necessarily limited to such starch crops as wheat, rye, rice, corn, barley, oats, millets and sorghums, white and sweet potatoes, manioc, yams, banana-plantains; such pulse crops as various types of dried beans and peas; oil crops such as coconuts, oil palms, rape, soybeans, peanuts, sunflower, cotton; sugar crops such as sugar cane and sugar beet; and flavor crops such as apples, citrus fruits, grapes, onions, and tomatoes. Cocoa, coffee, and tea may be included even though the last two provide no edible dry matter. Grasses cultivated for forage and important in agriculture, which have a wider climatic range, are not here regarded as major food crops; they do not provide food directly edible by man although indirectly they provide animal foods.

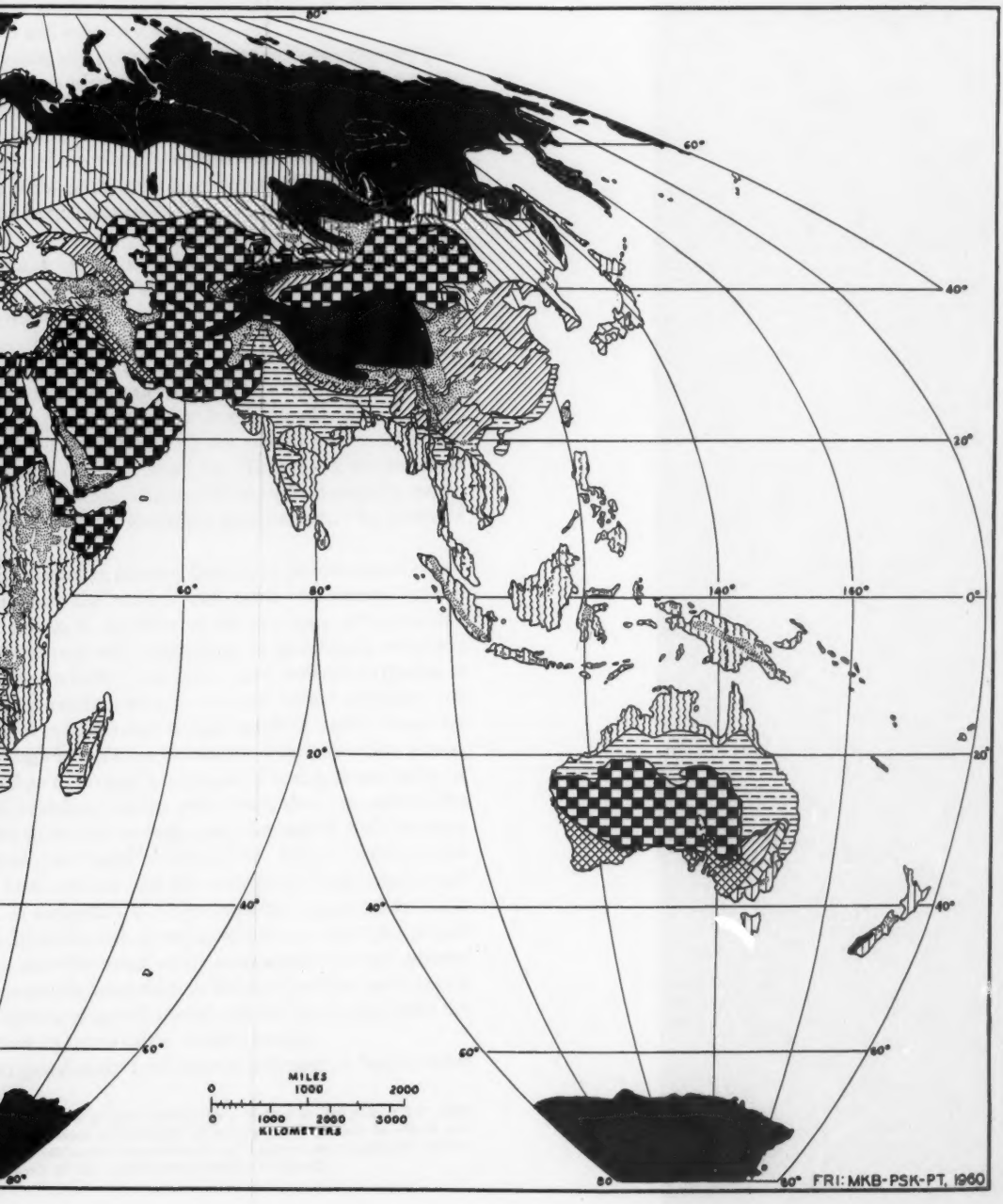
The solid black of Map 1 represents an attempt to specify those parts of the world's land area too cold for cultivation of major food crops. It seemed unfeasible to identify a single isoline circumscribing such a cold zone. Its warmer boundary was accordingly approximated on three criteria. In North America (Alaska excepted), the warm boundary is the isoline of 90 days free of 32° F. frost, as recently drawn on the basis of data from meteorological stations (see 2). Within the Soviet Union the warm boundary is the isoline of 1600° C. of accumulated summer temperatures above 10° C. (50° F.), commonly taken as a low-temperature limit on growth of spring-sown barley, the cereal least demanding of heat (*3*, p. 6; *4*). This isoline extends into warmer territory than a Russian-drawn isoline of 90 days free of "killing" frost (*5*, Pl. 35); that isoline is indicated by the line of white dashes. The Russian-drawn isoline of 90 days free of killing frost also circumscribes the non-Soviet cold zone in Asia, as well as the cold zones of Antarctica and Alaska. A more recently drawn but nearly identical isoline of 90 days free of killing frost (*6*, p. 11) encloses the cold zone of Europe. Since the Russian mapping appeared somewhat unrealistic for South America, Iceland, and New Zealand (where some parts have frost-free periods considerably longer than 90 days but the summers are too cool to mature major food crops), the cold zones of those areas are bounded by the equivalent of an average summer temperature of 50° F.[1] Perhaps, needless to say, certain relatively small spots on the earth's surface, chiefly represented by the peaks of mountains or mountain ranges, are

[1] See map in *7*, pp. 16–17. This map (A. E. Parkins' refinement of Herbertson's Thermal Regions) delineates territory characterized by "cold winter and cool summer; always cool in the Andes," and the temperature value of "cool" is 32°–50° F.


80°
60°
40°
20°
0°
160°
140°
120°
100°
FOODCROP AND NON-FOODCROP ZONES
OF THE WORLD
1 Cold non-foodcrop (under 90 days frostfree)
2 Dry non-foodcrop (under 10 inches annual rainfall)
3 Highland province (elevation over 5,000 feet)
4 Summer drought (Mediterranean) foodcrop
5 Cool temperate foodcrop
6 Mild temperate foodcrop
7 Warm temperate foodcrop
8 Subtropical foodcrop
9 Tropical foodcrop

Map 1


ZONES
rainfall)
Boggs' eumorphic equal-area projection
Boundaries generally as of 1939


80°
60°
40°
20°
0°
140°
160°
MILES
0 1000 2000
0 1000 2000 3000
KILOMETERS
FRI: MKB-PSK-PT, 1960

too cold for production of food crops; but these have not been so indicated on the map because of their small and isolated areas.

Although it appears impossible as a practical matter to achieve consistency of definition in mapping the many boundaries of the world's land surface in general too cold for cultivation of major food crops, the stated procedure may serve the purpose reasonably well. At least it can be said that the cold zone as mapped contains only about .7 per cent of the world's population while covering about 29 per cent of the land surface of the earth; and since absence of population means absence of crop cultivation, the factual intrusion of major food crops into the cold zone must be decidedly small.

The second problem is to mark off the world's land surface that is too dry for continuing cultivation of food crops in the absence of unusual or unnatural accumulations of water beyond the level of average annual precipitation. As a useful and consistently available moist boundary of this dry non-foodcrop zone we take the isohyet of 10 inches of annual rainfall as drawn in a recent world atlas.[2] On the principle that low temperature *per se* constitutes a firmer barrier than drought against foodcrop production, or is less amenable to human amelioration for purposes of producing food crops, we encompass with the 10-inch isohyet only that part of the land area which lies outside of the cold zone. Thus one of the indicated non-foodcrop zones in general precludes production of major food crops by reason of deficient heat, while the other precludes it—failing ameliorations—by reason of deficient moisture.

The 10-inch isohyet is of course not an absolute limit upon production of major food crops even when one ignores the natural flood lands and sumps and the artificial irrigation enclosed within it. In parts of the dry zone where rainfall comes in the cool season of the year and evaporation is accordingly relatively slight, a major food crop, fall-sown barley, can be matured without irrigation at a level of 7–10 inches of annual rainfall, though perhaps neither regularly (on account of annual variability of rainfall) nor at high levels of yield. There are also some parts, at relatively high latitudes or elevations, where the rainy season, coming in summer, is so cool as to permit production of spring-sown barley at a rainfall level slightly below 10 inches. On the other hand, there are parts of the world where summer temperatures are so high, and correspond with summer rainfall near 15 inches, that not even barley can be grown. Hence a more precise demarcation of the world's land area too dry for unirrigated food crops would no doubt call for an isohyet of somewhat less than 10 inches where winter rains prevail and at relatively high latitudes and elevations where summer rains prevail but the summers are mild; on the other hand, where summers are hot and summer rains prevail, an isohyet of somewhat more than 10 inches would be more appropriate. But within the appropriate range of annual rainfall levels, one finds the world as a whole mapped only in terms of the 10-inch isohyet.

The zone too dry for unirrigated major food crops as indicated in Map 1 covers

[2] See *8*, p. 4. The isohyet of 10 inches of annual rainfall there given does not accord fully with other mappings, as would be expected because of deficiency of information especially in Africa and Asia. Our mapping differs from Van Royen's only in excluding from the dry zone a moist area (above 10 inches of rainfall) in highland regions of the southwestern Arabian Peninsula.

some 17 per cent of the world's land area and includes about 2.6 per cent of the world's population. Perhaps an approximately equal percentage of the world's foodcrop acreage lies within it. Certainly, however, a large fraction of this acreage is irrigated, as notably in Egypt, along the Indus River of Pakistan, the Syr Darya and Oxus rivers in the southern USSR, in the American southwest, along the coast of Peru, and in scattered oases throughout the Saharan-Arabian-Iranian and the Mongolian dry zones. Close estimation might indeed demonstrate that the unirrigated foodcrop acreage of the world's dry zone as mapped constitutes a good deal less than 1 per cent of world foodcrop acreage.

THE HIGHLAND PROVINCE

Most, though not all, other parts of the world aside from the cold and the dry non-foodcrop zones are characterized by average conditions of temperature and precipitation which permit cultivation of one or another, or various combinations, of the major food crops. The aggregate area of the world outside the cold and the dry zones constitutes only some 54 per cent of the earth's land area, but nearly 97 per cent of the world's population resides within it. Foodcrop acreage and foodcrop production within this part of the world presumably also approximates 97 per cent of the unknown world totals.

It has seemed appropriate as a third step in the process of mapping to indicate (stippled areas on Map 1) certain regions outside the cold and the dry zones where, on account of elevations changing radically over relatively short distances, it is impossible to show at all clearly in a world map so small in scale the various climates that exist within it. Typically these are areas where mountain ridges or other sharp uplifts make for substantial changes in temperature over a short mileage, and also for substantial differences in precipitation between windward and leeward slopes. We have chosen to demarcate these climatically heterogeneous parts of the world as those lying at elevations above 5,000 feet,[8] in so far as also they exclude parts of the world lying within the cold and the dry non-foodcrop zones. In the main, food crops can be produced throughout the highland province so indicated, although especially in high latitudes the highlands contain some mountain peaks too cold for crop production and at many latitudes some intermontane valleys, lying in rain shadows, too dry for unirrigated crop production. Nevertheless wide areas within the highland province—the high plains of the western United States, the central valley of Mexico, the Bolivian altiplano, the Ethiopian plateau, and the Kenya highlands, for example—produce food crops abundantly. The principal useful purpose served by specific demarcation of the highland province may be to point out, at any given latitude, the zone of transition from a lowland foodcrop climate, usually rather homogeneous and of wide extent, to highland foodcrop climates usually at once different from the neighboring lowlands and diverse among themselves. The highland province is much less homogeneous with respect to climate, and hence with respect to food crops that thrive within it, than any of the areas of the world subsequently to be indicated as foodcrop climates.

[8] See 7, *passim*, for the contour line of 5,000 feet.

THE EXCEPTIONAL SUMMER-DROUGHT CLIMATE

If the total land surface of the earth measures about 57 million square miles, the portion of it aside from the cold and dry zones (26.3 million square miles) and the highland province (2.7 million) covers approximately 28 million square miles. The great bulk of this vast territory is characterized by regimes of rainfall such that the seasonal distribution is either rather even throughout the year, or shows seasonal peaks near the equinoxes in equatorial regions that are always warm, or has its seasonal peak in summer. Consequently rainfall and warm temperatures favorable for unirrigated agriculture usually coincide. There is, however, a relatively small fraction of the world (about 1.35 million square miles) wherein the rain necessary for unirrigated crops comes in the cool season of the year whereas the warm season is strongly characterized by drought. Food crops of annual habit of growth must, if unirrigated, be sown in these summer-drought regions after the rains have begun in the autumn, making the soil workable and germination of seeds possible. The annual food crops must then largely be of types able to germinate and to continue growth in the increasingly cool weather of late autumn and winter, ripening as temperatures rise but rainfall declines in the spring and early summer. Among the world's important cereals, wheat and rye particularly, but barley and oats also, have the requisite properties if sown in the autumn. But all spring-sown crops, including these grains, and additionally corn, rice, and the millets and sorghums, because they lack the necessary properties, are practically excluded except under irrigation. The unirrigated crop complex of this summer-drought-and-winter-rain, or Mediterranean, climate differs a good deal from complexes in other climates. Elsewhere in the world where annual food crops can grow under natural rain, sowings will take place at onset simultaneously of the rainy season and of the warm season (at higher latitudes) or under conditions of continuing warmth (at low latitudes).

The fourth step in the mapping here undertaken was to attempt to show the location (cross-hatched areas in Map 1) of this exceptional summer-drought climate in so far as it does not impinge upon the cold zone, the dry zone, or the highland province previously mapped. The cross-hatched areas are somewhat wider in extent than the Mediterranean climates as usually mapped by geographers following Köppen's system of classification, whereby that climate must meet temperature conditions of the coldest month ranging from 26.6° to 64.4° F. and the warmest month above 50° F., and rainfall conditions such that the driest month of summer has less than 1.2 inches of rain and the wettest month of winter at least three times as much. Taking first Trewartha's mapping of the Mediterranean climate (9, pp. 26–27), our procedure was (a) to exclude such small portions of it as overlapped our demarcations of the dry zone having less than 10 inches of annual rainfall and of the highland province, and (b) to add to the residual area some adjacent territories equatorward of the Mediterranean type proper in Africa and Australia, and eastward in Asia, which appear to be characterized in general by a cycle of summer drought and winter rain and have an annual rainfall less than in Mediterranean climates proper but more than the 10 inches of the dry non-foodcrop zone. These regions are usually classified climatically as "steppe," mostly tropical or subtropical.

TEMPERATURE PROVINCES IN REGIONS OF WARM-SEASON RAINFALL

Climates favorable to food crops other than in the heterogeneous highlands and in the summer-drought climate all receive their precipitation in seasons of warmth conducive to growth of annual food crops. Their area, as was pointed out above, vastly exceeds that of the highland and summer-drought climates combined. Within this huge area differences in temperatures, especially in the seasons of active crop growth, are important determinants of foodcrop complexes (irrigation ignored): bananas will not mature in Wales even where rainfall is as heavy as in banana-growing parts of Uganda, and white potatoes will not mature in those parts of Nigeria where annual rainfall is the same as in Ireland.

It is therefore a problem first to partition the foodcrop climates (aside from the highland and summer-drought types) in a manner meaningful with respect to potential geographical distribution of either foodcrop complexes or important food crops, so far as temperature *per se* places approximate geographical limits upon their distribution. Discussion could be protracted in the matter of choice of specific temperature circumstances that would best serve to divide this foodcrop area into several "temperature provinces" of significance to foodcrop production.

Briefly, however, those circumstances may be described as follows. (1) The surface isotherm of 68° F. average temperature in the *warmest* month is taken as establishing approximately, between itself and the isoline of 90 frost-free days which constitutes the warm boundary of the cold non-foodcrop zone, a temperature province (cool temperate) wherein production of corn (maize) for grain is excluded by low summer temperature. (2) The surface isotherm of 77° F. average temperature of the *warmest three months* is taken as establishing approximately, between itself and the surface isotherm of 68° F. in the warmest month, a temperature province (mild temperate) wherein production of cotton is excluded by low summer temperature. (3) The surface isotherm of 50° F. in the *coldest* month is taken as establishing approximately, between itself and the surface isotherm of 77° F. in the warmest three months, a temperature province (warm temperate) wherein production of citrus fruits is excluded by low temperature. (4) The surface isotherm of 68° F. in the *coldest* month is taken as establishing approximately, between itself and the surface isotherm of 50° F. in the coldest month, a temperature province (subtropical) wherein production of archetypes of tropical crops such as bananas, cocoa, and coconut are excluded by reason of low temperature. (5) The fifth temperature province (tropical) wherein such tropical crops may thrive is bounded on its cooler peripheries by the isotherm of 68° F. in the coldest month.

It seems not greatly a violation of common usage to designate the resulting five temperature provinces of the foodcrop zone, excluding highlands and summer-drought regions, as indicated above and on the map—*cool temperate, mild temperate, warm temperate, subtropical,* and *tropical.*

The evidence conveniently available for location of the several isolines here used to separate the temperature provinces requires brief comment, since a compendium of world mappings of the surface isotherms necessary to the purpose, as distinguished from isotherms adjusted to sea level, has not been found. The line of demarcation (not a specific isoline) indicating the cold periphery of the

cool temperate province and the warm boundary of the cold non-foodcrop zone, was described above (p. 286). At the other extreme, the isotherm of 68° F. in the coldest month, which circumscribes and provides the cool boundary of the tropical province, follows Parkins' mapping (*10*, pp. 151–65, and *7*, pp. 16–17), in his surface-temperature regions of the world, of the region called "always hot." Within the poleward extensions of this zone, however, we ignore the isotherm where it lies adjacent to designated highlands above 5,000 feet. The effect of this procedure is somewhat to obscure the existence of subtropical climates within the general poleward peripheries of the tropics; but their location and extent are perhaps sufficiently indicated by the mapped highlands themselves. The isotherm of 50° F. in the coldest month, the cool periphery of the subtropical province, also follows Parkins. That province and the tropical province are not permitted to overlap their neighbors, whether the non-foodcrop dry zone, the summer-drought province, or the highland province.

No single source was found showing satisfactorily the location throughout the world of the isotherm of 68° F. in the warmest month, which is taken as the low-temperature "limit" of corn and as separating the cool temperate province from the mild temperate province. Information had to be patched together from various sources, the more detailed being accorded preference (*5*, Pl. 33; *6*, p. 38; *11*, Map 8; *12*; *13*, pp. 70–71; *14*). It can be said that the isotherm as drawn in Map 1 seems to confine quite sharply the world distribution of corn acreage so far as low temperature restricts it, although some acreage representing corn sown for fodder or for sweet corn rather than for grain is found where the summer temperature is slightly lower, in the cool temperate province.

With respect to the separation of the mild temperate and the warm temperate provinces, the basic concept is that the division may reasonably follow a surface-temperature isotherm representing an average temperature of 77° F. in the three warmest months of the year, a level of temperature below which cotton does not mature.[4] This isotherm has been drawn for the United States (*16*, p. 10), but we have been unable to find its counterpart elsewhere in the world. For South America, however, readily available meteorological data indicate clearly that the isoline lies a little north of Montevideo and Buenos Aires on the east coast, between Rosario and Santa Fé farther inland and to the northwest, and east of Córdoba lying still farther inland and farther north but at higher altitude. In Australia, isolines of 75° and 80° F. for the individual hottest three months (December, January, and February) permit a rough approximation to the 77° F. summer isotherm (*17*, Figs. 1, 2, 12). For the Soviet Union and China-Korea we resort to the assumption that cotton cultivation presses as far as possible toward its temperature limit, so that the northern peripheries of the cotton acreage (see *8*, pp. 189, 191, and *6*, p. 44) indicate approximately the location of the isotherm, although for China isotherms of July temperatures of 75° and 82° F. afford a meteorological check (*13*, p. 71). While lacking adequate evidence, we take it that in India, southeast Asia, and South Africa all territory lying between the

[4] The concepts of 68° F. in the warmest month or 66° F. in the three warmest months, as the approximate low-temperature "limit" of corn production, and of 77° F. in the three warmest months as the approximate low-temperature "limit" of cotton production, both commonly accepted by geographers, appear traceable to Finch and Baker (*15*, pp. 29, 53).

subtropical province and the highland province may be predominantly of warm temperate type, with temperatures in the three hottest months exceeding 77° F.

RAINFALL LEVELS WITHIN FOODCROP PROVINCES

Within any of the nine differentiated regions shown in Map 1, levels of rainfall taken either annually or seasonally differ from one part to another. From the point of view of foodcrop production, the differences in rainfall levels are of negligible significance within the cold non-foodcrop and the dry non-foodcrop zones, these being zones wherein production of food crops is in general impossible under usual conditions, and accordingly no attempt is made in Map 2 to differentiate levels of rainfall within these zones. For a different reason, namely a degree of variability of rainfall levels within short distances, such as to preclude presentation on a small-scale map, no attempt is made to differentiate rainfall levels within the highland province.

Within each of the six remaining temperature provinces, however, levels of rainfall require to be differentiated if indication is to be given of relative hospitality to production of food crops without irrigation. While the tropical province experiences, if properly mapped, monthly mean temperatures always above 68° F., rainfall levels within it vary from 10 to well above 80 inches annually; crop complexes of the low-rainfall parts cannot be expected to prevail in the high-rainfall parts, and conversely.

The final problem of mapping, then, is to indicate within each of the foodcrop provinces, though not in the highlands, differences in rainfall levels which would be expected to affect distributions and complexes of food crops. It appears impossible, however, to follow at all closely the procedures used in marking off non-foodcrop from foodcrop climates and differentiating between the temperature provinces of the foodcrop zone, as by mapping approximate "limits" beyond which unirrigated food crops or particular food crops such as corn, cotton, citrus fruits, or bananas cannot be produced. The rainfall "limits" of many individual food crops seem, as compared with temperature "limits," to be more elastic. Moreover, rainfall occurring in the warm season, outside of the summer-drought province, may well be more important than annual rainfall for production of many major food crops, and one lacks world mappings of isohyets pertaining to warm seasons. Somewhat rough-and-ready procedures seem inescapable.

The first principle followed in Map 2 is to differentiate, within each of six temperature provinces, three levels of rainfall respectively designated as droughty, moist, and rainy. It would be possible on the basis of available world mappings of annual rainfall to differentiate not three but six levels of annual rainfall: 10–20, 20–30, 30–40, 40–60, 60–80, and over 80 inches (see *8*, p. 4). Experimental mapping has shown, however, that indication of more than three levels results in a world map—on the small scale feasible here—so complex as to be nearly unreadable. It has seemed advisable, therefore, to attempt within each of the six temperature provinces to make no more than a threefold differentiation, between rainfall levels that result at one extreme in high hazards to foodcrop production because of drought, at the other extreme in hazards of heavy rainfall and flood, with the less hazardous moist portions between them.

A second principle requires, however, that no single range of annual rainfall

be regarded as characterizing a condition of drought hazard throughout all provinces defined by temperature. On account of differential temperatures and evaporation, 10–20 inches of rain coming mainly in summer is much less hazardous in the cool temperate province than in the tropical province. Allowance is made in a rough way by designating as "droughty" the areas with 10–20 inches of annual rainfall lying in the cool temperate, mild temperate, and summer-drought provinces, the last being included because within it the rainfall useful to food crops occurs in the cool season of the year; but in the warm temperate and subtropical provinces we take 10–30 inches as characterizing the droughty areas, and in the tropical province 10–40 inches. The zone of 10–20 inches of rainfall in the mild temperate province, of 10–30 inches in the warm temperate and subtropical provinces, and of 10–40 inches in the tropical province is in general likely to be too dry for unirrigated corn and indeed for a considerable range of unirrigated food crops.

Similarly, no single range of annual rainfall can properly be regarded as characterizing "rainy" or "moist" areas throughout all five of the temperature provinces and the summer-drought province. In the cool temperate, mild temperate, and summer-drought provinces, the rainy extremes are perhaps sufficiently well indicated by regarding annual levels of above 40 inches of rainfall as representing rainy conditions, where excessive moisture creates handicaps for some important food crops. The rainy extreme may be taken as above 60 inches in the warm temperate and subtropical provinces; and above 80 inches in the tropical province. Hence the "moist" areas, relatively little handicapped for foodcrop production, are represented by ranges of annual rainfall of 20–40 inches in the cool temperate, mild temperate, and summer-drought provinces; 30–60 inches in the warm temperate and subtropical provinces; and 40–80 inches in the tropical province.

In Map 2, the six provinces that are subdivided according to rainfall level are denoted in color, and within each province the droughty portions are indicated by underlying black stipple, the moist portions by absence of stipple or hatch, and the rainy portions by cross-hatch. As a whole the map thus shows two non-foodcrop climates, one province, the highland, generally suited to food crops but undifferentiated with respect to temperature and rainfall, three foodcrop climates of the summer-drought province not strictly differentiated as to temperature (though with winters, therein the growing season of food crops, that are mild or cool), and fifteen foodcrop climates differing one from the other with respect to their combination of temperature and annual rainfall.

RELATIVE AREAS OF THE CLIMATES

Readily apparent from Map 2 are the relatively large fractions of the earth's land surface occupied by the cold non-foodcrop zone and the dry non-foodcrop zone. On measurement by planimeter, which yields somewhat imprecise results, the cold zone occupied about 16.4 million square miles and the dry zone about 9.9 million. Taking the earth's land surface, including minor inland and coastal waters, as about 57 million square miles, these two non-foodcrop zones occupy respectively some 29 and 17 per cent of the total.

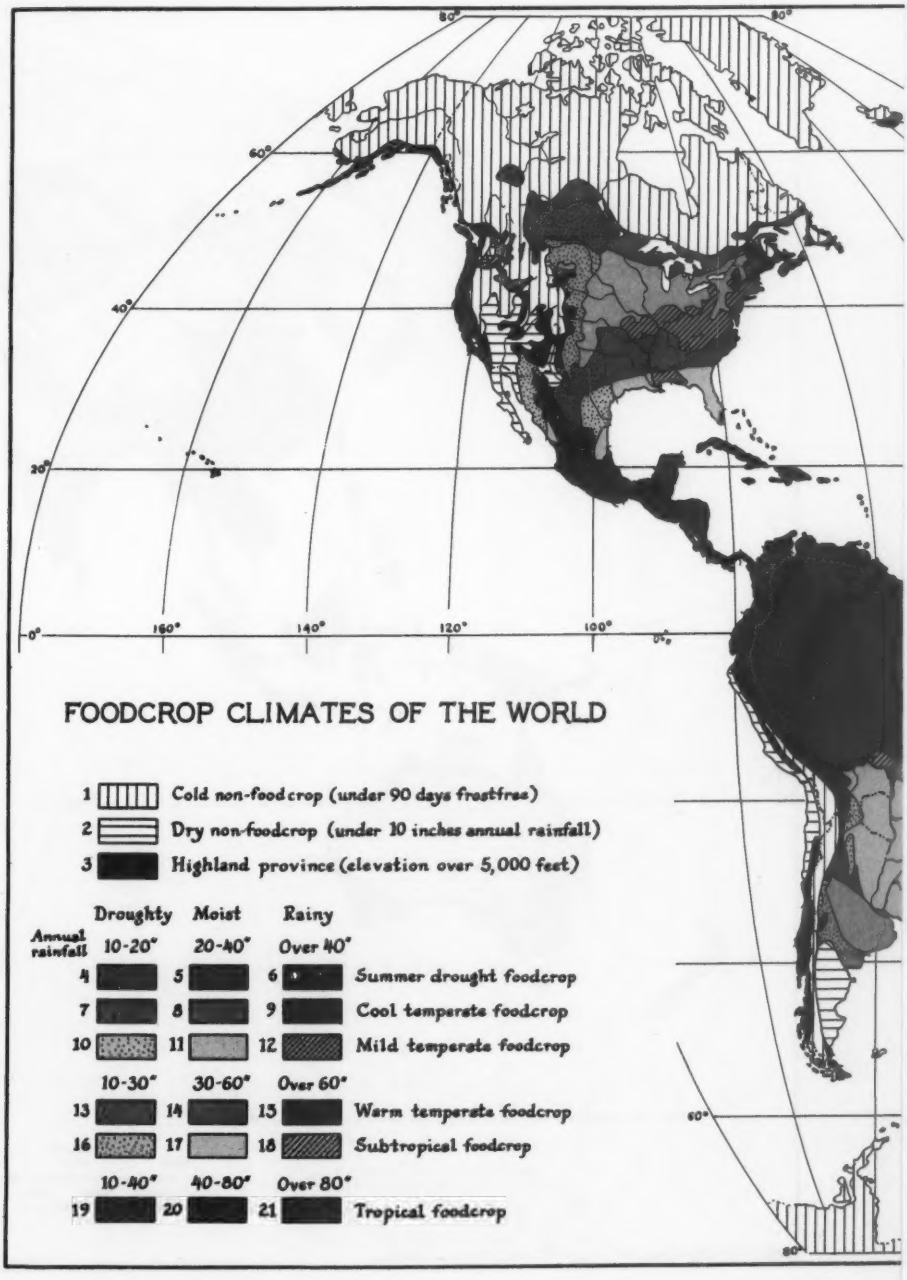
The highland province and the 18 foodcrop climates, constituting about 54

per cent of the land surface and measuring some 30.7 million square miles, are notably unequal in extent, as the following tabulation shows:

Zone or climate	Inches of rain	Million square miles	
Cold non-foodcrop zone	—		16.4
Dry non-foodcrop zone	—		9.9
Highland province	—		2.7
Summer-drought			1.4
Droughty	10–20	.65	
Moist	20–40	.60	
Rainy	over 40	.10	
Cool temperate			4.2
Droughty	10–20	1.49	
Moist	20–40	2.14	
Rainy	over 40	.56	
Mild temperate			3.5
Droughty	10–20	1.50	
Moist	20–40	1.53	
Rainy	over 40	.46	
Warm temperate			2.1
Droughty	10–30	.71	
Moist	30–60	.99	
Rainy	over 60	.44	
Subtropical			5.7
Droughty	10–30	2.19	
Moist	30–60	2.46	
Rainy	over 60	1.02	
Tropical			11.1
Droughty	10–40	3.15	
Moist	40–80	5.34	
Rainy	over 80	2.64	

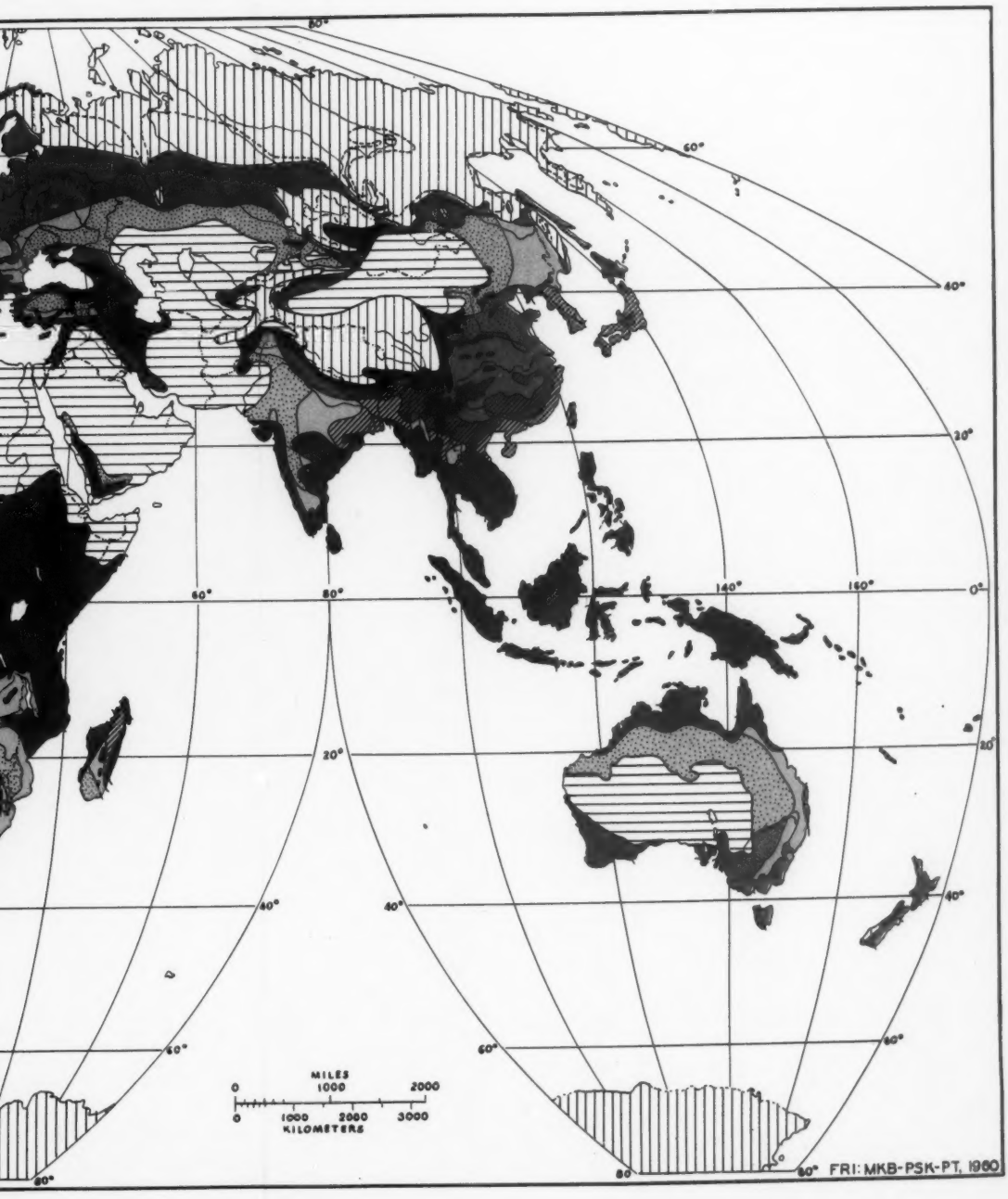
Most extensive in area is the moist tropical climate with some 5.34 million square miles, more than a sixth of the earth's surface climatically favorable to foodcrop production; the smallest is the rainy summer-drought climate of only .10 million square miles. The tropical and subtropical foodcrop climates, at 16.8 million square miles, exceed the temperate ones (here including highland and summer-drought) by more than 20 per cent.

On the whole, so far as can be judged impressionistically by reference to world maps of the distribution of population and of major food crops, notably the basic starch crops, the highland province, the summer-drought climates, and the nine temperate climates are at the present time relatively more fully settled and agriculturally exploited throughout their extent than are the six subtropical and tropical climates. Within each of these six climates, however, there are obviously sharp contrasts from one part to another in the degree of settlement and agricultural exploitation. Vast stretches of the droughty subtropical climate in Australia and Africa, for example, remain almost unexploited, while the same climate in India is heavily populated and cultivated. The moist tropical regions, while by no means comparable with summer-drought or mild temperate regions in density of population, are much more densely settled in continental Asia than in Africa, and in Africa than in South America. In the rainy tropical climate, there is high density


80°
80°
60°
40°
20°
0°
160°
140°
120°
100°
0°
60°
80°
FOODCROP CLIMATES OF THE WORLD
1 Cold non-foodcrop (under 90 days frostfree)
2 Dry non-foodcrop (under 10 inches annual rainfall)
3 Highland province (elevation over 5,000 feet)
Droughty
Moist
Rainy
Annual rainfall
10-20"
20-40"
Over 40"
4
5
6
Summer drought foodcrop
7
8
9
Cool temperate foodcrop
10
11
12
Mild temperate foodcrop
10-30"
30-60"
Over 60"
13
14
15
Warm temperate foodcrop
16
17
18
Subtropical foodcrop
10-40"
40-80"
Over 80"
19
20
21
Tropical foodcrop

Map 2

80°
60°
40°
20°
0°
Boggs' eumorphic equal-area projection
Boundaries generally as of 1939


80°
60°
40°
20°
0°
140°
160°
MILES
0
1000
2000
KILOMETERS
0
1000
2000
3000
FRI: MKB-PSK-PT. 1960

of population in the Philippines and Java, very low in interior Brazil and New Guinea. Such notable contrasts invite inquiry into their causes, and into the foodcrop potential of the vast regions now barely settled yet apparently as well suited climatically to foodcrop production as other regions that support dense populations.

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Roger W. Gray

THE CHARACTERISTIC BIAS IN SOME THIN FUTURES MARKETS

Like a trail through dense undergrowth, a market comes into being only through use, and is improved through increased use. The little used trail, because time and energy are wasted in locating or negotiating it, is more costly to use than the well trodden path. One may pay too much to the guide on a difficult trail to justify the passage; by the same token the payment to the factotum on a thin market may outweigh the advantage of its use. One may, of course, learn the trail (or market characteristics) himself; but this too entails a cost.

As the flow of traffic increases, undergrowth is killed, obstacles are moved aside, circumvented, or simply worn away; traffic itself provides an added safety factor; and a trail, in short, becomes more clearly marked and easily traversed. The trail may come to be maintained or artificially improved, as through paving, and traffic over it regulated. Yet should much of its traffic abandon it, a cumulative reversal of the development process is likely to ensue. Maintenance may become slipshod, leading to a further decline in traffic; and in time the trail may be completely abandoned, soon thereafter to disappear.

Most of the literature on the economics of futures markets has pertained to well-developed, thriving markets—especially those for the grains and cotton, the modern turnpikes of our metaphor. These were at one time thin markets, but we lack adequate data for a thorough study of the wheat, corn, or cotton futures markets during their early stages of growth nearly a century ago. Meanwhile other futures markets have been developed, some of them quite recently, and an increasing amount of information has become available about them. Some of these, for examples the soybean and cocoa markets, have recently grown to such proportions that the designation "thin market" is no longer applicable; indeed, these may be the two most thriving markets today. Other markets, after showing promise, have fallen into disuse. The bran and the shorts markets were abandoned by their erstwhile users. The butter market fell a victim of government pricing policies; the government did not eliminate the road, but provided an irresistable alternative which led to its abandonment—a fate which has nearly befallen the cotton futures markets, and has reduced traffic on a number of others. The onion futures market, in contrast, is one which the Congress has closed, without providing any alternative other than the treacherous path which this route superseded.[1]

[1] Public Law 85–839 makes it a misdemeanor to trade in onion futures.

The characteristic of some thin futures markets about which this paper centers is one which forces early abandonment of the trail analogy, although we shall return to it in concluding. The analogy is apt in suggesting a relationship between level of use and usefulness; but in thin markets, which are the chief concern here, we shall observe a tendency toward imbalance which is not elucidated by the trail analogy. Thin trails presumably accommodate travel in either direction equally well; thin futures markets apparently do not, although it is not obvious, and appears in some respects paradoxical, that this should be the case.

Some of the evidence (Table 1) on this score has been presented previously in another context (*3*); it is here interpreted more broadly than before, and at the same time a more intensive analysis of the performance of certain markets is provided. The results that are shown in this table are derived from a simple hypothetical trading routine that tests for balance or imbalance in a futures market by measuring statistically the general tendency for futures prices to rise over extended periods for which the beginning and ending spot prices were substantially the same. If maintaining a long position in a commodity future, by routinely switching out of the expiring future into the next one, produces profits (losses) over a lengthy period when spot prices do not change, then the futures market may be said to chronically under (over) estimate future prices—to be unbalanced, lopsided, or biased (downward or upward) in the terminology that will be employed here. The ideal date for switching from one future to another in such a routine is at or near the first trading day of the delivery month, this being the time at which the futures contract effectively "becomes" a spot commodity, in that delivery can then be made on the contract, thus making it possible to obtain a spot price series in the futures price series.

In all cases shown in Table 1, the commodity future was "purchased" at the closing price on the first day of the delivery month of the preceding (expiring) future. Thus, for example, the March wheat future was "purchased" on December 1, 1949, at 218½ cents; this was "sold" and the May future "purchased" on March 1, the May "sold" and the July "purchased" on May 1; and so on seriatim until March 1, 1958, when the March future was "sold" at 220¾ cents to complete 41 successive trades. Very nearly the same routine was followed in all cases, even to trading in the same five futures each year for bran and shorts as for wheat, corn, oats, and coffee, even though every month was a delivery month in bran and shorts futures. In the case of soybeans, the delivery months differed slightly from the others and also changed during the period, but still the trading dates were virtually the same as for the other commodities. The *t*-ratios in the final column test the hypothesis that the average price change in the various series of trades did not differ from zero. The first five markets tested were balanced over the period considered in the sense that this hypothesis is accepted; most of the remaining markets were unbalanced in the sense that the hypothesis is rejected. The *t*-ratio is a general statistic that permits ready comparisons among the various commodities and statements of probability (or level of significance) for each. There may also be interest in the next to last column, which gives the average profit (or loss) per "trade" before commissions.

The characteristic lopsidedness of some thin futures markets poses questions about their use that are addressed in the remainder of this paper. How, why, and

TABLE 1.—*t*-RATIOS COMPUTED TO TEST THE HYPOTHESIS THAT THE MEAN PROFIT FROM MAINTAINING A LONG POSITION DOES NOT DIFFER FROM ZERO

(Grain prices in cents per bushel; coffee and cocoa in cents per pound; bran and shorts in dollars per ton)

Commodity and market	Dates of first purchase and last sale	Prices at beginning and ending dates		N	$\bar{X}$	*t*-Ratios[a]
		Expiring future	Next future			
Corn	Dec. 1, 1949–	128¾	130½			
Chicago Bd. of Trade	May. 1, 1958	126¼	125¼	42	−.35	.234
Wheat	Dec. 1, 1949–	218½	218½			
Chicago Bd. of Trade	Mar. 1, 1958	220¾	217⅞	41	−.22	.116
Oats	Sept. 1, 1948–	71⅜	74¼			
Chicago Bd. of Trade	Mar. 1, 1957	74¾	73	41	−.18	.152
Soybeans	May 1, 1955–	249⅝	241[b]			
Chicago Bd. of Trade	July 1, 1959	223⅜	212⅛	25	.37	.107
Cocoa	May 1, 1955–	32.15	32.79			
N.Y. Cocoa Exchange	Dec. 1, 1959	31.27	30.39	23	.02	.032
Soybeans	Nov. 1, 1948–	243	242⅛[b]			
Chicago Bd. of Trade	Sept. 1, 1953	259⅞	255⅞	25	9.23	2.221
Cocoa	Sept. 1, 1947–	30.93	28.20			
N.Y. Cocoa Exchange	May 1, 1955	32.15	32.79	39	1.29	1.189
Wheat	May 1, 1949–	216½	202½			
Mpls. Grain Exchange	July 1, 1959	205⅛	207⅛	41	3.35	2.279
Brazilian Coffee, N.Y.	May 1, 1950–	45.10	43.20			
Coffee & Sugar Exch.	Dec. 1, 1958	42.00	37.90	43	1.73	1.788
Bran, Kansas City	July 1, 1947–	58.50	51.50			
Board of Trade	May 1, 1952	53.00	49.00	24	2.35	1.886
Bran, Kansas City	July 1, 1953–	40.75	43.75			
Board of Trade	Dec. 1, 1956	41.75	43.88	17	−1.14	1.827
Shorts, Kansas City	July 15, 1947–	70.00	60.00			
Board of Trade	Sept. 1, 1952	62.25	60.90	26	2.63	2.398
Shorts, Kansas City	May 1, 1953–	55.45	50.75			
Board of Trade	May 1, 1956	48.00	no quot.	15	−1.54	2.429

[a] For N = 30, a *t*-ratio of 2.042 is significant at the 5 per cent level.

[b] In computing *t* for soybeans, adjustments were made for price change, because the periods chosen had substantial net price change from beginning to end.

by whom are lopsided markets used? This concern with the physiology of the markets looks ultimately toward their growth prospects. Some markets have outgrown their bias, which can only mean that there have been reasons for, and ways and means of, using markets *against or despite* the bias.

There are ample indications that many users of lopsided markets are aware of their characteristic feature, so that it cannot be supposed that such markets are used under the mistaken impression that they are balanced, or used without any regard to the question of balance. The so-called discounts in the coffee and cocoa markets have been widely publicized (*1, 11, 12*) and are well known in com-

modity commission firms as well as within the coffee and cocoa trades. Coffee importers, for example, take short positions in the market in full awareness of its tendency to underestimate prices by a few cents a pound annually.[2] Moreover, contract specifications in most markets have been revised from time to time in order to counteract apparent tendencies for the contract to favor buyers or sellers as demand or supply conditions change in the course of time. These revisions manifest awareness of bias, and stimulate further awareness. In conversations with users of the Minneapolis wheat futures market, the writer has encountered numerous references to the unbalanced situation there. Similarly, officers of milling firms in Minneapolis have alluded to the underestimates of price that prevailed on the Kansas City bran and shorts futures markets. The possibility that markets remain in use owing to ignorance of their lopsidedness is ruled out, not only by the foregoing considerations, but by the fact that the measurements of bias presented above cover a sufficiently long period to have made the bias apparent to any observant regular user. We turn to consider use patterns in these markets on the assumption that awareness of their imbalance does exist, reaffirming the need to understand how, why, and by whom they are used.

THE MARKETS FOR BRAN AND SHORTS

The futures markets for bran and shorts, after a quarter century of mostly unhealthy existence, died in November 1957 when the Board of Directors of the Kansas City Board of Trade suspended trading. Trade in these futures was never large, although it had flourished briefly between World War II and the Korean War. At that time price ceilings were encountered, the removal of which in 1953 failed to stimulate revival. The level of trade then sank rapidly and last minute efforts to revive it in the summer of 1957 were fruitless.

The distinctive feature of the bran and shorts markets was the overwhelming dominance of large hedging positions on both sides of the market. A larger proportion of the total open contracts consisted of contracts reported as hedging than for any other regulated market, and the difference between reported long and reported short hedging was seldom large. The speculative ratio in these markets was probably lower than that for any other futures market (*6*, Table 3, p. 194).

No quantitative breakdown of the hedging by industry affiliation is available, but it is possible to infer the pattern from trade sources and other studies. A survey of hedging practices in the mixed-feed industry (*13*) revealed that little hedging of inventories (short hedging) of bran and shorts was practiced; and that some use was made of the futures markets for procurement purposes, i.e., buying of futures contracts and taking delivery on them. The market discussion which appeared as a regular feature in the *Southwestern Miller*, a leading trade journal, frequently referred to buying of futures contracts by millfeed dealers or by feed manufacturers, but not to other sources of demand. The only selling referred to was that of flour mills, presumably the dominant source of supply of these futures contracts. Feed mixers did little or no forward selling of their feeds, and there is no indication that purchases of futures contracts were undertaken in conjunc-

[2] Even those importers who may have been unaware of the historical evidence that the market tended to underestimate future prices had evidence, in the mere presence of the discount at the time the short hedge was placed, that they incurred prospect of a hedging loss.

tion with such a practice. Nearly all of the sales, in brief, must have come from flour mills, with a scattered few from feed mixers protecting inventory. The purchases probably came from both millfeed dealers and feed mixers—dealers in protecting forward sales to mixers; mixers in anticipation of requirements but with no fixed price offset. Flour mills may have bought some futures contracts in protection of forward sales, but they were predominantly *sellers*; dealers and mixers may have sold some contracts to protect inventories, but they were predominantly *buyers*.

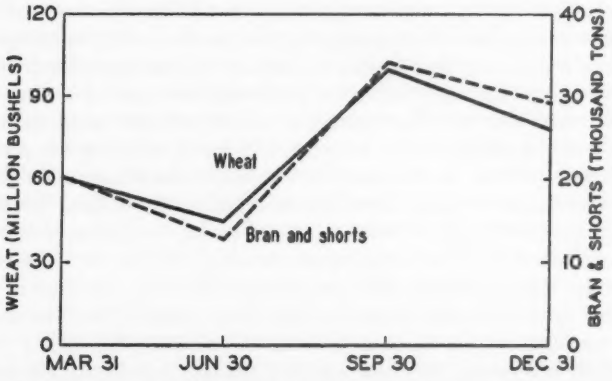
Evidently the futures markets for bran and shorts served primarily those who would do the buying and selling anyway, and little risk was transferred to outside speculators. There is evidence that these futures markets were used for merchandising purposes to a larger extent than other futures markets, in that approximately 10 per cent of all transactions eventuated in delivery, in contrast to the usual proportion of less than one per cent and a next highest proportion of 2.6 per cent (for wool tops) among all regulated markets during 10 postwar years (1947–56). The bran and shorts contracts called for sacked delivery in boxcars in the Kansas City freight yards, a feature which would facilitate delivery because most millfeeds emanating from Kansas City would have moved in this way in normal merchandising.

The normal operational hedging of flour mills calls for a long position in wheat futures when their net cash position (in wheat and flour) is short, and vice versa. Thus, for example, a forward flour sale is accompanied by a purchase of wheat futures; a purchase of wheat by a sale of wheat futures. Forward flour sales, whether hedged in wheat stocks or in wheat futures contracts, are slightly "over hedged" in that wheat produces more than just flour. A full balance is struck only when the by-product millfeeds, along with the flour, are sold ahead. This could be accomplished either by forward sales to millfeed dealers or feed mixers, or by sales of futures contracts.

The millfeeds, and also the manufactured feeds which consume about half of the millfeeds, are produced at a relatively even rate the year around. The marked seasonal variation in the level of open contracts in millfeed futures, and the close correspondence with the pattern of unfilled flour orders, both shown in Chart 1, indicate the close linkage between the millfeed futures markets and flour-mill operations. This suggests that the flour mills using bran and shorts futures have tended to determine the level of their use, since there is no good reason to expect either such wide variation or this particular pattern of variation from the demand side of these markets. At the same time it should be noted that nothing approaching full use of the bran and shorts futures markets was ever made by flour mills. It would have required from 10 to 20 times the level of open contracts reached in bran and shorts futures during their peak use (1947–51) to have fully hedged the unfilled flour orders of reporting mills. What proportion of these forward flour sales may have been matched by forward millfeed sales is unknown, but the bran and shorts futures markets accounted for a very small proportion.

Against this background of market use it is possible to interpret the price-behavior pattern of the postwar period. As was shown in Table 1, both of these markets were lopsided against the buying side (underestimated prices) for sev-

CHART 1.—Average End-Quarter Open Contracts in Bran and Shorts Futures Compared with Average End-Quarter Unfilled Flour Orders, 1947–56*



* Open contracts in bran and shorts futures from U.S. Dept. Agric., Com. Exch. Auth., *Commodity Futures Statistics* (Stat. Bul. 256), July 1955–June 1956; wheat sold into flour from compilations made by the Miller's National Federation, which includes most United States flour mills.

eral years (1947–1952), then for a somewhat briefer period, prior to their demise, both overestimated prices. There are two other major factors the timing of which corresponds fairly closely with the remarkable about-face in price behavior. The first of these is the price level: for both commodities the price was high by historical standards throughout the period of downward bias in futures prices, fell quite abruptly during a brief intervening period, and remained at relatively low levels during the period of upward bias in futures prices. The other corresponding factor is the level of open interest, which best measures the level of use that a market receives. This, along with the price level, reached an all-time peak in the early postwar period. Price controls occasioned by the Korean War discouraged market use and open interest declined sharply. A modest recovery was made in 1952–53, but this was shortlived, as the following year witnessed a drastic decline from which the markets never seriously rallied.

The correspondence in timing between the reversal of the bias and the changed levels of price and open interest allows the following explanation of the bias to be inferred. The habit or tradition of futures market use was well established in the flour-milling industry, in marked contrast to the feed-mixing industry. In seeking to round out their operational hedging policy by selling millfeed futures, millers evidently encountered great reluctance on the part of feed manufacturers to assume forward commitments. Yet at relatively high millfeed prices the millers built their short position up despite the general reluctance to buy, sacrificing something from prevailing price levels in order to project these levels into the future. Even the minor fraction of millfeed production that thus became reflected in the futures market forced it badly out of shape. A full routine hedging policy such as millers commonly employ in the wheat futures market would presumably have forced the millfeeds markets to absurdly low price levels.

The millers nevertheless sought to resume their use of the futures market after

the Korean War, only to find that open interest at half the prewar level was placed at a price sacrifice, partly owing to declining price levels. As the millers then quickly shied away, the little enthusiasm for futures trading that had been kindled among the feed interests was soon dissipated in a market that had now turned against them. Because of the experience gained in the market, or because prices had fallen, or both, the shoe was on the other foot after 1953. Buyers used the market at a premium just as sellers had previously used it at a discount. So long as millers were now unwilling to use the market on even terms, not even the modest level of trading that had been achieved in the early postwar years could be sustained. In their last-minute efforts to revive the market, officials of the Kansas City Board of Trade directed their appeal to the millers. Yet the same tradition that found millers initially disposed to use the market now militated against continued use. Their long experience with the wheat futures market had taught them that its greatest value was in any emergency; that even in unusual price conditions they could trade with little price effect. The bran and shorts futures markets had not accommodated them reasonably through a period of high prices; why should they now sustain it through a period of low prices?

Although the foregoing account is inferential, the factual pieces not only fit together in this arrangement, but taken together in whatever arrangement support some implications for market growth and development. A combination of three facts—the incomplete use made of these markets, the extraordinarily large proportion that was hedging, and the reversal from buyers' to sellers' market—together imply a particular *kind* of hedging. This is what is called *selective* hedging, which may be undertaken or not, depending upon price prospects, as distinct from routine hedging which assumes no need for forming judgment on price prospects. Hedging which depends so heavily upon price and market considerations seems to fit the usual definition of speculation. Hence the somewhat paradoxical implication of these facts is that while these markets illustrate the possibility of futures markets that subsist entirely upon hedging, they force a reconsideration of the distinction between speculation and hedging. Moreover, the limited usefulness of these markets suggests that no market which fails to attract a good deal of participation by speculators can adequately provide for routine hedging.[8]

If the degree of imbalance in these markets inhibited their growth, and gives evidence of the need for speculation in a futures market, it nevertheless did not prevent their continued use over a period of years. When this view of the markets is taken, accentuating the level and kind of use that their characteristics permitted instead of that which was prevented, it implies strongly that a weak futures market is better than none at all. Such a market provides at least "the freedom . . . to make a sale . . . that would not otherwise be possible" (7, p. 561), and a means of averting the plight bemoaned by one merchant, whose product has no futures market, in the following words, "What a frustrating thing . . . to sit for months in a falling market and be unable to sell even though . . . you were the only one who knew it was going to fall" (5, p. 42).

[8] This suggestion, which finds further support in the remainder of this paper, has been spelled out in a recent paper by the same author (3).

THE COFFEE MARKET

The New York coffee futures market has not yet been completely abandoned, but it is one of those over which traffic (in our earlier metaphor) has been much reduced by a government price support program. First opened in 1882, this trail carried much traffic in the first decade of its existence and has enjoyed subsequent periods of (somewhat less) heavy traffic as well. It has been repaired from time to time, and has undergone infrequent major alterations, as must any thoroughfare in adapting to changing traffic requirements. More recently the Brazilian government has provided, in its coffee price support programs, a serious obstacle to some sorts of use and an alternative to other sorts of use of this route, with the result that traffic has fallen to a low ebb. Recently a business day passed without a single transaction in coffee futures; yet noteworthy as is the example that this market provides of the time honored principle that futures markets cannot thrive where prices are administered, its example of stubborn survival in these circumstances illustrates the equally cogent, less obvious, and more invigorating principle that hedging sustains futures markets.

The coffee futures market is not only thin (the level of open contracts since World War II has averaged somewhat less than the inventory of *one* large roaster) and lopsided (see Table 1), but its price characteristics have been of a kind that have been a source of confusion in futures trading theory. Coffee prices have been high by historical standards during the postwar era and, with only brief and partial exceptions, the pattern of futures price quotations has been for the near future to be highest and each subsequent future to be lower than the preceding one. This phenomenon manifests the error, or bias, in the market, which has recurrently underestimated the future price level and has thereby produced profits for routine buyers and losses for routine sellers of futures contracts.

These circumstances are widely recognized, and the response on the part of the coffee trade has been rational. A system of hedging or, for that matter, speculating too, has been widely recommended, if not so widely adopted. This system, variously known as "buying the discounts," a "perpetual hedge," or "carrying inventory in futures," consists simply of routine buying of futures contracts on the theory that these are underpriced and must tend to rise in price as the contract approaches maturity. This system is recommended by leading brokerage firms, and has been explained in pamphlets, trade journal articles, and books emanating from these firms or their affiliated research bureaus (cf. *1, 11, 12*).

Though the foregoing analysis of the market has been adequate from the practical trading standpoint, closer inspection reveals superficialities in the trade analysis from the standpoint of the functioning of futures markets. These, when superimposed over the superficialities of the standard textbook analysis of futures trading, compound confusion. The widely divergent interpretations of futures price behavior given by well informed tradespeople and by outstanding economists are confusing not only because they diverge, but because both are mistaken.

In British parlance, "backwardation" is the term used to describe the situation in which spot prices are higher than futures prices, and near futures higher priced than distant futures; "contango" is used to describe the opposite relationship. Keynes (*4*, p. 143) spoke of "normal backwardation" because he thought of

futures prices as "normally" reflecting a risk premium paid to speculative buyers by hedging sellers; this would necessarily result in backwardation exceeding contango in the long run and thereby appearing to be the more nearly "normal" of the two relationships. The trade jargon in the United States, on the other hand, refers to "inverted" markets instead of backwardation; *and uses the term "normal" to describe what Keynes called a contango* (cf. 2, Ch. 13).

Another glance at Table 1 will suffice to indicate that it is by no means obvious which is the "normal" price relationship in futures markets. For wheat and corn futures on the Chicago Board of Trade, not only for the periods covered here but for much longer periods, the average difference between spot and futures prices does not differ significantly from zero. Thus neither backwardation nor contango may be said to be normal. For a few postwar years backwardation prevailed in the soybean market, only to be superseded by balance as the market grew to maturity. In bran and shorts, extreme backwardation for four years was followed by extreme contango for three years, which was followed by death. In coffee and in wheat at Minneapolis, alone of the markets listed here, does backwardation appear to be normal; yet this relationship did not obtain in the interwar period on the Minneapolis wheat market nor in coffee prior to the valorization schemes. In no market does contango appear as a persistent tendency.

It seems preferable in view of the facts to forget about "normal" price relationships and to say that highly developed futures markets neither overestimate nor underestimate prices over very long periods of time; but that other, less well used markets, may persistently overestimate or underestimate prices over extended time periods (of at least a decade in some cases). The former are referred to here as balanced markets; the latter as lopsided markets.

Among the alternative pairs of terms that are used to describe the price relations among futures—contango vs. backwardation, premiums vs. discounts, carrying charges vs. inverse carrying charges—the last pair has the distinction of implying that the price relationship described affects the willingness of potential stockholders to carry hedged stocks of the commodity. The markets where "carrying charge" is the term commonly used by the trade are in fact markets in which traders have been keenly aware that substantial positive carrying charges had to exist when there were large stocks to be carried. Working, going a step farther, has called the carrying charge a price of storage, and has pointed out that an inverse carrying charge is therefore a negative price of storage, which can exist because some stocks must be carried for business convenience alone (9). Viewing the carrying charge (positive or inverse) as a price of storage opens a fruitful line of reasoning concerning the influences that determine the price of storage.

It has been shown that for certain markets the price of storage (carrying charge) is determined, as might reasonably be expected, by the volume of total stocks of the commodity (8; 9). That relationship could be seen most readily for such commodities as wheat in the United States prior to entry of the federal government as a major holder of stocks. Thereafter, the market-determined price of wheat storage depended, on the demand side, on the volume of *commercially* owned stocks.

Biased markets, in which prices are *generally* underestimated, require a somewhat different interpretation of an inverse carrying charge. In such a market an

inverse carrying charge may reflect seasonal or other temporary shortages, and in *addition* the general underestimate of future prices. It would be impossible to say for any particular price constellation how much inverse carrying charge was in reflection of temporary shortage and how much was due to bias in the market, yet the inversion would tend to be greater during a period of acute shortage and would also tend to vary seasonally for a commodity having a pronounced seasonal variation in production.

The fundamental difference in interpretation between inverse carrying charges in a balanced market and in a chronically lopsided market has not been drawn in any literature that I am familiar with.[4] The simplest expression of this difference is that in a lopsided market the inverse carrying charges represent, at least in part, underestimates of price and hence advantage to the futures buyer, whereas in a balanced market they represent no better buys on the average than do carrying charges, and neither represents, on the average, a better purchase than sale. This distinction is of course implicit in the widely recommended "discount buying program" in lopsided markets, but the recommendation amounts to superficial induction so long as the underlying distinction is not explained. The tendency has been instead to reason about inverse carrying charges as though they reflected the same circumstances in both balanced and lopsided markets. An example of this tendency, illustrating the error that may result, will be provided next.

In a recent book devoted to futures trading, the very competent research director for a leading brokerage firm devotes a chapter to hedging in "normal" and in "inverted" markets. Of the latter he writes, "distant months will ordinarily fluctuate more slowly than near months" (2, p. 136). Before turning to some evidence that supports the *opposite* of these statements, I should point out that I sought and expected evidence in support of the above hypothesis, and was surprised and puzzled to discover such clear counter evidence as will be introduced here. The theory of the price of storage (9) requires that the spread between near and distant futures prices be interpreted *as* a price of storage, which of course suggests no necessary link between changing price *levels* and changing price *spreads*. Inverse carrying charges reflect current (usually seasonal) shortages of supplies and positive carrying charges reflect current (seasonal) surpluses. The aforementioned expectation of greater variability in near than in distant futures prices, valid as it is for the major futures markets, rests upon considerations other than the price of storage. The different spread behavior for coffee futures, to be introduced below, could be interpreted in much the same manner; i.e., it could be said that a price of storage is reflected in the spreads, that conditions of relative surplus and shortage are reflected in spread variations which are superimposed upon the general downward bias, but under circumstances that have tended to cause downward price movements of the distant future to be associated with decreases in the price of storage, thus causing the near future to move less than the distant.

The bias in the coffee futures market in Table 1 is considerably understated. This happens because an interim period of very different price behavior is included in the period covered there. In presenting a more detailed analysis of the coffee market here, therefore, a somewhat different period has been chosen, con-

[4] Working dealt with a balanced market and thus did not encounter need for explaining the somewhat different behavior of unbalanced markets.

sisting of two unbroken periods which are separated by the briefer omitted period. After the results for this period have been shown, the distinctive characteristics of the omitted period will be described.

In order to keep the change in price level to a minimum after eliminating the interim period, as is necessary to avoid distorting the results, the beginning and ending dates for the entire period are somewhat different from those shown in Table 1. The Brazilian coffee contract was first "purchased" on December 1, 1949, (March contract) and the long position maintained in the manner described earlier by switching futures on the first day of each delivery month until May 1953, when sale of the May future then held was followed by no purchase until December 1, 1955. On that date the program was renewed, and continued to March 1, 1959. The net change in price level for these two periods together was −2.39 cents per pound, computed as follows:

December future on December 1, 1949	46.90
July future on July 1, 1953	56.67
Price change	+ 9.77
December future on December 1, 1955	49.90
March future on March 1, 1959	37.74
Price change	−12.16

Net price change = −12.16 + 9.77 = −2.39

Yet such was the bias that the gross profit for the 34 trades was 46.5 cents per pound and the *t*-ratio for the average profit was 2.88, which is significant at the 1 per cent level.

A test for results of *spreading between near and distant months* was conducted in an analogous manner over exactly the same period. In addition to buying the next future on the first day of the delivery month of the expiring future, the spread program involves also sale of the second future beyond that being purchased; so the complete spread program comprises the following routine:

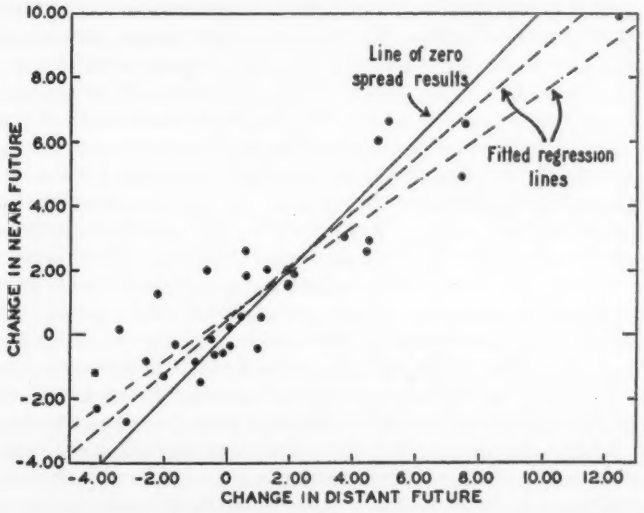
On March 1 close out any existing positions and buy May and sell September
On May 1 close out any existing positions and buy July and sell December
On July 1 close out any existing positions and buy September and sell March
On September 1 close out any existing positions and buy December and sell May
On December 1 close out any existing positions and buy March and sell July
etc. seriatim.

This spread program turns out to have been a good hedge of the aforementioned discount buying program, in that the *distant months fluctuated more than the near months,* with the consequence that the spreads widened with declining prices and tended to narrow (though only slightly on balance) with rising prices. On an average, to state the facts in somewhat oversimplified form but with sufficient accuracy, near month prices rose about 90 per cent as much as distant month prices, and declined about 50 per cent as much. If the discount buying program was hedged by taking one spread position with each long position, the *t*-ratio was 3.59 instead of 2.88. The coefficient of variability in the near month price changes was 2.00, compared to 3.35 for the distant months. The correlation coefficient between change in spread and change in near future price was −.32 and between

change in spread and change in distant future price was −.69. Chart 2 shows the results for the 34 trading periods in such a way as to reveal the tendency for distant futures to decline and advance more than near futures. In this chart, the "line of zero spread results" of course represents a tendency for near and distant futures to rise and fall in the same amounts. The fitted regression lines show unequivocally that price changes in the distant future tended to be greater, not less, than in the near future.

CHART 2.—Relation Between Price Changes Between First Days of Successive Delivery Months in Near and Distant Futures, Brazilian Coffee, December 1, 1949–May 1, 1953 and December 1, 1955–March 1, 1959

(*Cents per pound*)



A more complete explanation of spread results in this market would entail considerations of seasonality and changes in the level of stocks, but we sought here to emphasize the relationship between spread results and price changes. We next interpret these results in terms of market characteristics and use.

There can be little doubt but that the dominant characteristic of the coffee market during the period under review has been the price support program of the Brazilian government. This program has been such as to leave little semblance of a free market in coffee. Much of the time price announcements were made on a sporadic and even day-to-day basis, leaving the private speculator in the position of having to outguess or anticipate the Brazilian officials. American speculators had little taste for risking their money on such a guessing game. There have also been discrepancies, the incidence and magnitude of which are inherently uncertain, between actual and officially quoted prices. These have been of sufficient importance, and the Brazilian policy sufficiently capricious, that the trade has probably doubted the sustainability of prevailing price levels during much of this period. Exchange rate manipulations, elaborate quota systems, and

similar devices have cast a shadow of uncertainty over coffee prices. Three major consequences tend to result from such conditions:

(1) The price-supporting government must provide for the carrying of the surpluses, seasonal as well as persistent, that accumulate. Private trade interests are unwilling to carry stocks over and above those required in their operations.

(2) Speculators shun the market. The futures market has of course provided the most convenient vehicle for speculation in coffee prices, and it is here that decline in speculator participation would be concentrated.

(3) Any lack of confidence in the sustainability of prices would be reflected in discounts on forward positions in futures and forward markets alike.

In a market so dominated by a price support program, it is not surprising that its futures market should wane. The imbalance of the futures market undoubtedly reflects the reigning uncertainty and the inadequacy of speculation, both of which flow from the Brazilian support efforts, but it may also reflect, quite directly, the hedging that remains to sustain the futures market. To anyone accustomed to thinking of hedging as more or less routine protection of inventories, the behavior of coffee futures prices must immediately suggest prohibitive hedging costs. Who are the hedgers and what are the circumstances in which they are willing to pay the implied costs? The chief sellers in this market are the importers who, when they buy coffee in Brazil for later resale in the United States, have occasion to cover the unsold coffee in futures. The first and most important characteristic of their use of the coffee futures market is that its level is very low and declining. The circumstances in which importers hedge in this market are rare; out of recognition of the costs, their use of the futures market is highly *selective. Ex post,* the coffee futures is one which underestimates prices; *ex ante,* the hedger then is drawn into the role of price forecaster. As he comes to recognize that this discount market more or less repeatedly corrects itself at the expense of the seller, he realizes that its *general* usefulness to him is greatly impaired, and that its usefulness has come to depend upon his ability to select the specific occasions on which it may reward him more than it costs him. Where he might, as a routine hedger in a balanced market, do his import buying with strict regard to the price *relationship* between the coffee purchased and the relevant future, he must instead, as a selective hedger in a lopsided market, seek more or less continuously to forecast what the spot price will subsequently be. If, in his judgment, the relevant future at the time is a good forecast of what the spot price will be subsequently, then he may hedge in futures. If he deems the future a low forecast, he may sell in the forward green coffee market, a non-futures market in which sales of particular lots of coffee are made for forward delivery. If he thinks neither of these markets will serve him well, but nevertheless has a sanguine view of the future level of coffee prices, he may well buy coffee for importation without any hedge.

The importer has also the incentive to hedge as an aid to financing his transaction. Bankers have a standard practice of advancing more funds on hedged inventory, a practice which may sometimes be questionable in a case where routine hedging is so costly as it would be in the coffee market, but which would never-

theless encourage hedging. Smaller profits per unit on borrowed capital can be preferable to larger profits per unit on owned capital.

Another characteristic of price behavior in this market is that spreads have tended to widen more after they have already widened relative to the previous delivery month; and to narrow more after they have already narrowed. I infer that spreads have tended to widen owing to the pressure of hedge sales in the distant future. On the assumption that it is the initiative or lack of initiative of selling hedgers that tends to dictate the spread pattern (which widens on price declines and is stable or narrows slightly on price increases), then this tendency of spread movements to continue suggests that the selective hedging of importers is successful. The short hedges, that is to say, tend to cost more when they are worth more. That the hedger does use distant futures is indicated in the fact that the concentration of open interest by delivery months is further removed from the current date in coffee than in other futures markets—including those where long period stock carrying is facilitated by hedging. Incidentally, the carrying of selling hedges in *distant* futures, even on a routine basis, would be not quite so costly as our measurement of bias implies, because the distant future does not rise so much on an average as does the near future.

It is also true that price concessions have been made, at various times and through various devices, by Brazilian sellers. These would presumably augur price weakness and serve as a further stimulus to hedging, at the same time that the favorable buying terms in Brazil and unfavorable selling terms in New York futures might be viewed as mutual offsets.

Biased markets, as we have seen, are thin markets, used for hedging by only a small segment of potential hedgers. In the coffee market, during the years when it has been biased downward, hedging of stocks has been done mainly by importers. The inverse carrying charges that have prevailed in that market, representing a negative price of storage, have impelled importers to do business, so far as possible, on a hand-to-mouth basis. To be able to serve their customers, they must carry some stocks, not only afloat, but also in United States warehouses; but they have tended to keep those stocks near a minimum to hold down costs.

Looking to the *causes* of the continuously negative price for hedged storage of coffee, it appears clearly a price determined largely by governmental action in Brazil. The government there has chosen to carry coffee stocks at its own expense. This presumably would have resulted in a market price of storage averaging about zero if the coffee futures market could have remained a balanced one. But because speculators tend, wisely, to avoid a market where the price is subject to arbitrary change by any group (or government) that holds dominant influence, the coffee market was left with little ability to carry the load of risk that some private holders of coffee stocks wished to shift to it. Consequently the price of hedged storage of coffee has been persistently negative.

The period which has been omitted from the foregoing analysis comprises 12 successive "trading periods" extending from July 1, 1953 to December 1, 1955. More information is available for this period than for the longer one because the Federal Trade Commission conducted an investigation of coffee prices which covered a part of this period (*10*) and for which data were procured that are not

regularly available. Prices of all futures had reached OPS ceilings in March 1953, as a result of which trading was suspended. Shortly thereafter ceilings were removed and prices moved upward to levels which the controls had previously prevented their reaching. This was followed by a major crop scare in July, with widespread and insistent reports of frost damage, leading to general price advances, with little or no effect on price spreads. This price rise had no sooner run its course than the Brazilian government announced, early in December, a 25 per cent increase in the loan rate on coffee, precipitating the sharpest price increase of the entire postwar period. A group of Brazilian traders immediately began buying in all futures (except the expiring December future), continuing their buying until the price of each future had risen by approximately 25 per cent. It seems obvious that these traders assumed that futures prices had conformed to the pre-existing loan rates and that the new loan rates, which they viewed as sustainable, would affect the entire set of futures prices alike. Subsequently, as the Brazilian buyers accepted their profits, traders in the United States bought all futures in what proved to be an abortive tailing action. Losses were taken in these positions as prices declined moderately in all futures, after which prices declined still further as prospects for the 1954 crop appeared reasonably good and as the 1953 frost damage reports proved ultimately to have been overdrawn. Thus ended six successive trading periods during which price movements were very wide (the *average* change in near futures price during these six intervals was larger than the *largest* change in any other single interval since the war) and during which spread changes were only nominal as virtually the same wide changes occurred in the distant as in the near futures.

Following these six intervals of very wide price change and of stability in the spreads came six additional trading periods of moderately wide price change and extreme spread widening. Near futures prices rose in four of the six intervals, for a net increase of 18.3 cents per pound at the same time that the distant futures underwent a net price decline of 1.5 cents per pound. The *average* spread change for these six intervals was considerably larger than the *maximum* spread change in any other postwar trading interval. There may have been no true downward bias of futures prices during this period; the large inverse carrying charges that emerged are reasonably attributable to the fact that stocks of coffee in both the United States and Brazil fell to far the lowest levels of the postwar period and a real current shortage was reflected in the price structure.[5]

The 12-interval period just discussed, but eliminated from the earlier analysis, was one which saw the partial restoration of coffee prices to more natural in-

[5] The Federal Trade Commission implies that there was something undesirable in the presence or actions of the Brazilian traders during the period of the survey, when Brazilian traders held substantial net long positions. This seems a curious interpretation for a market which has been so chronically out of balance as this one for lack of buying; but the authors did not have the survey period in this larger perspective. For the twelve trading periods which embrace the F.T.C. survey period, the average "bias" in the coffee futures market, measured as the change in price of the near future minus the difference between successive near futures, was .58 cents per pound, in contrast to 2.31 cents per pound for the remaining 34 trading periods. The "bias" was almost eliminated during the period of the F.T.C. study! Their analysis of spreads concludes: "The erratic fluctuations in the spread among the various futures indicates that the market reflected numerous reappraisals of the expected future course of coffee prices. The tendency for the distant futures to sell at discounts under the nearby futures indicates a general lack of confidence in the future level of coffee prices. The many apparent reappraisals in market judgment as reflected by the change in spreads may reflect the lack of adequate knowledge of stocks and crop conditions" (*10*, pp. 421–425). Yet the spread fluctuations seem less erratic in the light of this interpretation.

fluences. A real shortage caused prices to rise above the loan rate, which was subsequently raised. Later the shortage of stocks in the United States led to a steep inverse carrying charge.

OTHER MARKETS

The other markets represented in Table 1 have not been analyzed so intensively as the coffee and millfeeds markets. Two of these markets, those for soybeans and cocoa, deserve comment because of the interesting change that has taken place in their "balance," and the bearing that this has upon the observations made at the beginning of this article.

During the early postwar period, while the soybean futures market was growing but not yet thriving, it was biased against sellers. The writer has seen no published reference to this imbalance, but was recently told by good authority that it was a quite widely recognized phenomenon around the Chicago Board of Trade at the time. With subsequent growth this market achieved balance, as Table 1 indicated.

A similar thing happened to the cocoa futures market, which has been widely publicized as a discount market in which a routine buying program was recommended. In the example published by a large brokerage firm, the period covered is embraced by the *first* period shown for cocoa in Table 1 (*11*, p. 46). The profits from routine buying happen not to have been significant at the 5 per cent level over this period; but there is no quarreling with the example which shows merely that such a program *was* profitable. Subsequently, as the level of use of the cocoa market rose substantially, it too became a well balanced market, as indicated by the very low average profits from maintaining a long position since 1955.

It is not only true, then, that among the markets tested here the thin ones appear to be lopsided and the better used ones balanced; but in at least these two cases the relationship applies to the same market at different stages of its development. The implications for futures market growth are worth contemplating. The futures markets for soybeans and cocoa are quite possibly the world's two best used commodity markets. Certainly soybeans must be ranked first, in view of the sheer volume of business transacted in this market. The cocoa market might seem an unlikely candidate for the second rank, until due attention is given to the potential level of use, for cocoa is not so important a commodity in commerce as wheat or a host of other commodities. A clearer impression of the level of use of the cocoa market is conveyed in a comparison with coffee. Coffee imports into the United States average about five times as large in volume as cocoa imports, yet open interest in cocoa futures has averaged about three times that in coffee futures in recent years. The potential futures market use that inheres in a commodity trade depends of course on the nature and extent of that trade. Coffee and cocoa are strongly similar commodity trades from a United States viewpoint, suggesting that the cocoa futures market is approximately 15 times as well used as the coffee futures market. Apparently speculators who felt unable to cope with the kind of influence exerted by the Brazilian government are not similarly afraid of that exerted by the African cocoa marketing boards.

Two *of* the best, if not the two best, futures markets in the world were, only a few years ago, thin and lopsided. Before despairing utterly of prospects for the

recovery of sick markets, the revival of dead ones, or the creation of new ones, it may be well to think of these two.

It is also worth noting that a market which undergoes a very substantial decline, such as the Chicago wheat futures market, can retain the balance that was achieved at earlier higher business levels. Even though most of the stock-carrying that was formerly done by using this market is now done by the government, a trade that has learned the value of a futures market apparently does not relinquish it easily, but continues to find sufficient buying and selling opportunities in it to keep the market in balance. Yet in the cases of bran and shorts, commodities that have not been supported in price or stockpiled, the markets never achieved balance because the trade never came close enough together in appraisals of price prospects to encourage further use and bring price ideas even closer together.

So we end where we began. The more a market is used the more useful it becomes, as with a trail. But evidence has been provided on a distinction which may be important to future analyses of growth prospects or diagnoses of weakness in particular markets—namely, that thin markets tend to be lopsided. Instead of asking what might be needed to stimulate traffic, or why traffic fails to develop, it may be desirable to first ascertain the breakdown according to direction and then ask, figuratively, why traffic in one direction does not develop to balance that in the opposite direction. Evidence has been provided that some thin and lopsided markets have been sustained by hedgers. A futures market on the margin of subsistence will probably always be a somewhat unbalanced market on which hedging costs are high. The significant requirement for balance is enough participation by speculators to balance the hedging. The thriving markets are those with adequate speculation to serve hedging needs economically.

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ARNOLD B. LARSON

MEASUREMENT OF A RANDOM PROCESS IN FUTURES PRICES*

This paper presents the results of application of a new method of time-series analysis, which appears to give the first really satisfactory answer to the question of whether commodity futures markets facilitate excessive daily price fluctuations. The method uses an entirely new test statistic, the index of continuity, rather than autocovariance as do virtually all other methods. In order to show why the new statistic is needed, I will first sketch the current status of the relevant area of time-series analysis, and demonstrate the failure of existing methods to solve the problem at hand.

RECENT TRENDS IN TIME-SERIES ANALYSIS

From the viewpoint of the economist engaged in research into economic relationships, progress in development of time-series analysis can be gauged by the kinds of "cycles" which can be detected. These may be true sine waves of fixed period and amplitude, or the apparent cycles which occur in series with purely random movements, or they may be intermediate types such as the disturbed cycles of autoregressive schemes. Usually the processes which generate the cycles embody or reveal interesting economic relationships, and the parameters of the processes can be given economic interpretation.

Much of the early work in time-series analysis was concerned with the decomposition of a series into trend, seasonal or other cyclic, and random components. Often the cycle so isolated was of indeterminate character. Among the first procedures which at least by implication addressed themselves to the question of the type of process which generates cycles was the periodogram. It tested for cycles of fixed period against the counter hypothesis of a purely random series. A systematic development of the theory of stationary stochastic processes, beginning in about 1930, permitted the formulation of a large sample theory for the harmonic, autoregressive, and moving average processes. The parameters of even high order processes can be estimated, although the methods are quite cumbersome and almost require the use of electronic computers. These three processes—harmonic, autoregressive, and moving average—are thought to correspond to many real processes, including many of those in operation in economic situations.

There appear to be many difficulties involved in applying the methods of

* Paper read at a meeting of the Western Farm Economics Association held at Stanford University, on August 24, 1960. Thanks are due to Patricia Cedarleaf for preparation of the charts.

analysis of stochastic processes to economic data, in spite of the seemingly satisfactory state of the theory. Since many economic series are short, the large-sample estimates are of doubtful validity. The process in operation in the series may not be stationary, and in fact may be intermittent or at times completely obscured by random factors. Most of the methods of parameter estimation depend fundamentally on the correlogram, that is, the graph of successive autocorrelation coefficients. Empirical correlograms have been shown to have highly autocorrelated terms, and to depend heavily on the particular sample drawn. Results of correlogram analysis of economic time series have been generally disappointing to date, being both inconclusive and of doubtful validity.[1] Usually only the first one or two terms of the correlogram have been used, and even these often have not differed significantly from zero. However, it must be granted that the possibilities have not been exhausted for successful application of correlogram methods.

Often in time-series analysis greater interest attaches to the *type* of process in operation than to the particular values of the parameters of a process once specified. The type of process is interesting to the scientist because it determines the nature of the mechanism in operation, and the mechanism may be basically unaltered under a wide range of parameter values. Furthermore, the type of process may be genuinely in doubt. Tests of significance, which in general help us choose between alternative parameter values, are in consequence not as important as are tests of goodness of fit, which choose between alternative specifications of process type. Sometimes more than one specification is acceptable on the basis of the test of goodness of fit. Procedures for choosing among the acceptable specifications can be devised, but one can never determine by purely statistical means that *the* true process has been found. All statistical investigation encounters this problem, of course, but it is of special importance here.

THE THEORY OF ANTICIPATORY PRICES

A time series, such as a commodity futures price series, can be analyzed in one of two ways. First, one may apply formally and naively the methods for estimating each of several processes, and choose the best fitting process as the one which is presumably in operation in the series. This will normally involve some *a posteriori* rationalization of the existence of such a process in the series. The test of goodness of fit will not ordinarily provide conclusive evidence that this is the true process, but quite possibly the rationale will be sufficiently plausible so that the results may be accepted.

The second approach, which seems preferable because of the lack of power of the tests of goodness of fit, is to determine the type of process which is implied by the structure of the market, or other institution being studied. Then only the order of the process and certain parameters need be estimated by statistical means. It is still necessary that the data fit the specification satisfactorily, but acceptance of the hypothesis rests primarily on its *a priori* probability, based on economic considerations.

Something close to the first approach is most often used in economic analyses.

[1] See Gerhard Tintner, *Econometrics* (Wiley, 1952) for a number of applications and discussions of the results.

A process of one of the well developed types is fitted after the most casual theorizing, just to see if it gives a good fit. It may be that more sophisticated and realistic theories do not ordinarily lead to stochastic processes of one of the standard types. But if this is true, a conscious process of simplification with an eye to retaining the essential features of the economic structure in the stochastic process would be more likely to yield valid results.

In this study the second course is pursued and an attempt is made to derive the stochastic processes implied by two theories of market price formation, and to subject the theories to empirical test by estimating the implied processes. The two theories are not mutually exclusive, but they do present opposing views about the probable existence and importance of excessive price fluctuations generated in futures markets. No attempt is made at complete expositions of either theory. Rather only those facets which touch upon the implied stochastic process and the central question of excessive fluctuation are developed at all fully.

The first theory is that of Professor Taussig (*1*). He held that the equilibrium price is only roughly determinate, and that the market price is free to fluctuate within a penumbra of uncertainty about the equilibrium price. At the edge of the penumbra there would be a reaction, or at least a check, presumably caused by equilibrating forces asserting themselves, returning the price toward equilibrium.[2] Since no one knows just where within the penumbra the price should be, it moves in this zone in response to the slightest impulse, which may be completely unrelated to market information. Furthermore, and this is perhaps Taussig's main point, movements away from equilibrium in the penumbra of uncertainty will not necessarily call forth an immediate return to equilibrium, but may well produce further movement in the same direction. Taussig assigns a big role to the market manipulator who, for example, may sell in hopes of inducing further sales and an artificially low price, at which he buys and awaits the return of price to equilibrium. The timing of the reversal of price movement varies, and sometimes the manipulator fails in his objective.

Taussig's theory unfortunately cannot be reformulated as a stationary stochastic process, at least without considerable simplification. A Markov chain with reflecting barriers corresponding to the edges of the penumbra might be an approximate model. The analogy is far from complete, however. For instance Taussig's theory apparently differentiates between price changes caused by manipulation and those caused by market information, and hence one cannot apply the same transition probabilities, which imply the same probable subsequent course of events, to the two situations. The probabilities to be assigned should perhaps depend on the path previously taken, which would make the process non-Markovian and make analysis much harder.

Even the correlogram implied by the theory is not clear. Presumably there would be numerous short runs of various lengths, many but not all of them followed by abrupt reactions. This might imply rather high negative correlation coefficients for several days' lag, for a series of price changes. Or if the runs are

[2] This phenomenon resembles in many respects the "support" and "resistance" levels of chart traders, although the support and resistance seems often to be attributed to more esoteric causes than equilibrating forces. If we grant that they are the same, we would conclude that price does not immediately bounce off the edge of the penumbra and continue toward the center, but rather remains near the edge for some time.

of several days' duration there may be positive correlations followed by negative ones. The correlogram, which completely describes the autoregressive and the moving average schemes, appears to tell little about this kind of process.

It would evidently be difficult or impossible to test Taussig's theory by standard statistical methods, because it fails to conform to any of the well developed stochastic processes. But maybe it is wrong anyway. Past prices have had to stand the test of market clearing and presumably cannot be grossly in error very long. The primary task of the traders in the market is thus reduced from the formidable one of estimating the correct price *level* to the much more modest one of gauging the price *changes* appropriate to changes in the demand and supply conditions. This they might well be able to do. So maybe the penumbra is not there.

Holbrook Working has developed a theory of anticipatory market prices which reflects quite a different view of market behavior (2). He argues that anticipatory prices depend on expectations regarding the future course of events affecting demand and supply of the commodity being traded. Traders base their expectations on market news, which in broad and highly organized commodity markets, he suggests, tends to be generally accurate, timely, and relevant.

In an ideal market, existing knowledge of market conditions would be reflected in current price, and any new information, showing altered conditions, would produce a price movement. Truly new information emerges randomly, and so price movements would tend to be random. Working's model of price movement in an ideal market is thus a random walk; that is, price is the cumulation of random movements. Equilibrating forces restrain the random walk, of course, but during the life of any one future the random movements predominate. These random movements, far from being blind stumbling around in a penumbra, would be movements to accurately estimated new equilibrium prices.

No actual market behaves exactly like an ideal market. Many commodity futures markets approach the ideal, and differ principally in that traders react with varying skill to varying sources of information, and so some of the response to price-making forces is delayed. The initial response is inadequate, and subsequent corrective response is in the same direction. The delayed response is a rather small fraction of the total, and is dispersed over a considerable number of days, in a highly variable pattern.

This completes the essential economic argument, but for mathematical reasons, to reduce the number of parameters to be estimated, it is further specified that the average pattern of dispersion is approximately rectangular; that is, a constant percentage of the delayed price response occurs on each day of the dispersion span. This is a gratuitous assumption, and as a matter of fact we will modify it shortly, but even major changes in the specified pattern do not seem to call for revision of the economic interpretation.

With this assumption, Working's theory of anticipatory prices leads directly to a moving average stochastic process of order equal to the length of dispersion span and with uniform weights. Price changes are a moving average of the price changes which would have occurred had the market been perfect. The process is not quite stationary, since the variance of price influences varies over time, but this is not likely to be a serious discrepancy.

For large dispersion span and low per cent dispersed, the weights of the moving average process are very low. A moving average stochastic process which generates a series is completely determined by the mean and variance of the series and by the correlogram equal in length to the order of the process. The very low weights, with resulting low values of correlation coefficients, coupled with the difficulties mentioned above, make estimation of the process from the empirical correlogram extremely difficult.

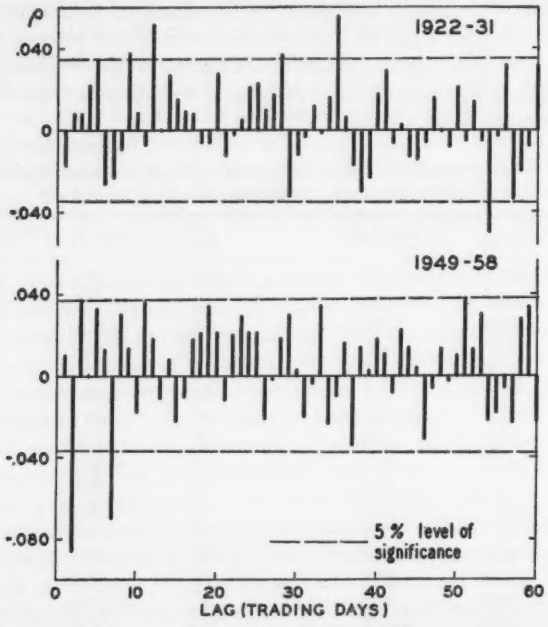
TABLE 1.—AUTOCORRELOGRAMS OF CLOSE-TO-CLOSE PRICE CHANGES, CORN FUTURES PRICES, CHICAGO, 1922–31 AND 1949–58

Lag	1922–31	1949–58	Lag	1922–31	1949–58
1	−.017	.012	31	−.003	−.020
2	.008	−.086[a]	32	.012	−.004
3	.008	.037[b]	33	−.001	.034[c]
4	.022	−.000	34	.016	−.024
5	.035[b]	.033[c]	35	.056[a]	−.010
6	−.026	.013	36	.006	.016
7	−.023	−.070[a]	37	−.017	−.034[c]
8	−.009	.030[c]	38	−.030[c]	.014
9	.038[b]	.013	39	−.023	.003
10	.009	−.018	40	.018	.018
11	−.007	.036[c]	41	.029[c]	.011
12	.052[a]	.018	42	−.006	−.008
13	−.000	−.011	43	.003	.002
14	.027[c]	.008	44	−.013	.014
15	.015	−.022	45	−.014	.004
16	.009	−.010	46	−.006	−.031[c]
17	.008	.018	47	.016	−.006
18	−.006	.021	48	−.000	.014
19	−.006	.034[c]	49	−.008	−.002
20	.028[c]	.021	50	.021	.010
21	−.012	−.012	51	−.005	.037[b]
22	−.002	.020	52	.014	.013
23	.005	.029	53	−.005	.030[c]
24	.021	.021	54	−.050[a]	−.022
25	.023	.021	55	−.003	−.018
26	.010	−.021	56	.032[c]	−.006
27	.017	−.001	57	−.034[c]	−.023
28	.037[b]	.018	58	−.020	.028
29	−.032[c]	.030[c]	59	−.008	.034[c]
30	−.012	.003	60	.032[c]	−.022

[a] Significant at 1 per cent level.
[b] Significant at 5 per cent level.
[c] Nearly significant.

The correlograms of the series of changes in closing prices of corn futures on the Chicago Board of Trade for two ten-year periods, 1922–31 and 1949–58, up to lag 60, are shown in Table 1 and Chart 1. Several of the coefficients of correlation are significantly different from zero, but no clear pattern emerges. For instance, significant values seem to be as likely at high orders of lag as at low. Also, high positive coefficients frequently occur adjacent to high negative values. More-

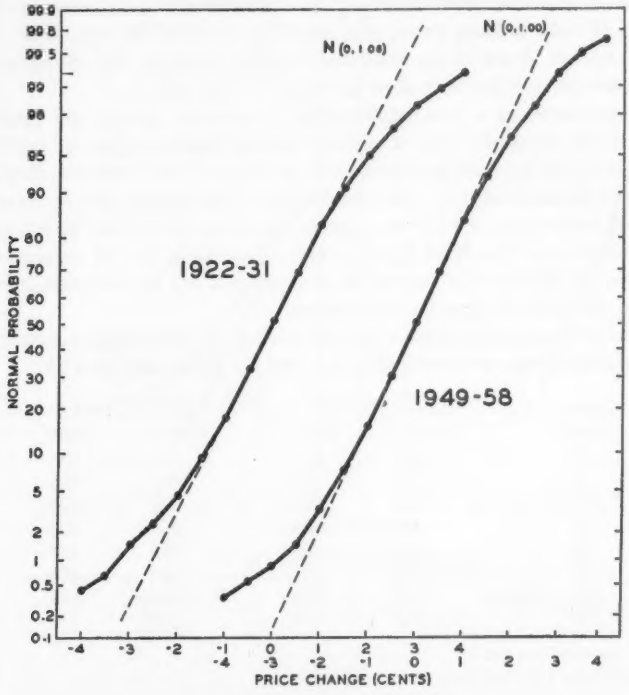
CHART 1.—Autocorrelograms of Close-to-Close Price Changes, Corn Futures Prices, Chicago, 1922–31 and 1949–58



over, there appears to be no correspondence between the correlograms for the two periods. The general appearance of the correlograms virtually rules out the possibility of a low-order process of any sort, and strongly suggests that the series is indeed a random walk. Because the correlogram method lacks power to detect moving average processes with very low weights, we should not accept this negative conclusion on the basis of this evidence.

The erratic patterns in the correlograms may arise in part from the nature of the distributions of price changes, shown in Chart 2. The distribution for each 10-year period has mean near zero, and is symmetrical and very nearly normally distributed for the central 80 per cent of the data, but there is an excessive number of extreme values. Also, some of these are quite extreme, being 8 or 9 standard deviations from the mean. If these extreme values occur randomly the estimates of correlation coefficients are consistent, but the confidence intervals shown are somewhat too narrow. Indeed, the cross-product of two of the higher extreme values would be of the same order of magnitude as the autocovariances found in the study. Examination of the pattern of occurrence of all price changes in excess of three standard deviations from zero, and of the cross-products of these changes, indicated that they have no special autocorrelation properties, and it is assumed that the data are essentially homogeneous and that underestimation of the variance of the autocorrelation coefficients is probably the only problem arising from presence in the data of an excessive number of extreme values.

CHART 2.—Distribution of Close-to-Close Price Changes, Chicago Corn Futures, 1922–31 and 1949–58, Compared to Normal Distribution



THE INDEX OF CONTINUITY

Holbrook Working developed the test of the index of continuity specifically to analyze anticipatory prices. The index is based on the ratio of the range of a series on an interval to the sum of the ranges of the subintervals within the interval. The subintervals are of equal length and non-overlapping. The series of values of index of continuity, designated H, for one-day subintervals and interval lengths of 2, 4, 8, . . . , 256 days, trace a curve which forms the basis for estimation procedures. Positive values of H occur when the range of the series tends to exceed the expected range of a random-walk series over intervals of a given length. Positive values of H thus imply movement of the series predominantly in one direction; in other words, relatively long, but perhaps interrupted, runs and positive autocorrelation. Negative values of H imply an excessive number of reversals in the series, so that the range tends to be less than that of a random-walk series. Autocorrelations between members of a series at any lag within the interval length tend to affect the index of continuity for that interval length similarly. Hence the index of continuity test relaxes the assumption of rigid lag between initial and corrective movements, and substitutes the more realistic assumption that the correction occurs sometime within a given interval of time.

Since the index of continuity is based on the range, i.e., the difference between maximum and minimum, it is rather difficult to treat analytically. With the assistance of two associates,[8] Working has determined the approximate distribution of H for a random series, thus providing a test of the hypothesis that a series is random. Some of the basic mathematical work on the test remains to be done, but enough has been done to make the test usable.

The parameters of a "rectangular-tailed" dispersion pattern, and hence the weights of the particular type of moving average stochastic process postulated in Working's theory, have been estimated by Monte Carlo methods, dispersing a random-walk series in ways corresponding to several moving average processes (*3*). Such dispersions give rise to a family of curves of H-values which can be approximated by a family of logistic curves depending on the parameters of dispersion. In this way the parameters of dispersion can be estimated from the empirical H-curves for one-day subintervals.

Empirical H-curves for the two ten-year periods of corn prices, and the logistic curves fitted to them, are tabulated below, and are shown in Chart 3A:

Interval length	1922–31 Period		1949–58 Period	
	Empirical	Fitted	Empirical	Fitted
2	−.006	.001	.012	.001
4	−.022	.002	.008	.003
8	−.033	.006	−.007	.009
16	−.032	.017	−.003	.023
32	.005	.038	.030	.051
64	.048	.074	.082	.100
128	.133	.112	.181[a]	.164
256	.148	.139	.253[b]	.220

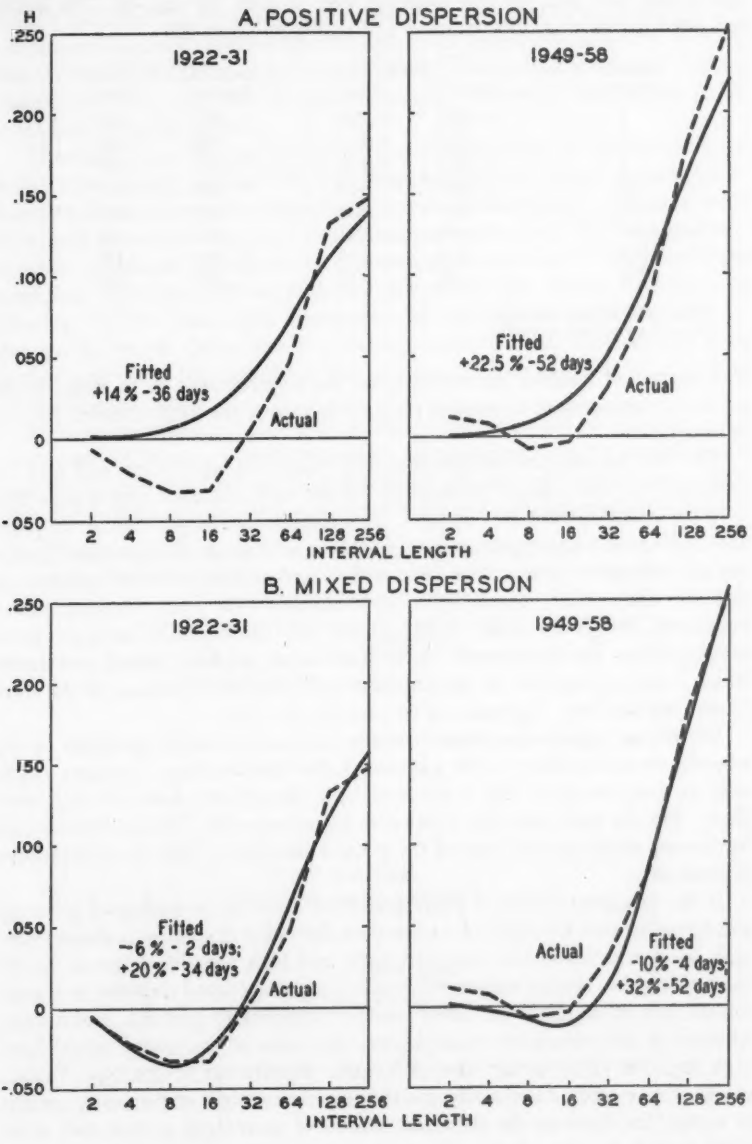
[a] Significant at 5 per cent level.
[b] Significant at 1 per cent level.

These fitted curves correspond to dispersion parameter estimates of 14 per cent dispersed over 36 days for the 1922–31 period, and 22.5 per cent dispersed over 52 days for the 1949–58 period.

The fit is fairly good. The general character of the empirical curve conforms rather well to the fitted theoretical curve. The negative H-values at low interval lengths are definitely anomalous, however. A much better fit is achieved if it is assumed that the weights of the lower portion of the dispersion span are negative. This might result from profit-taking by quick-turn traders, or if some group of traders tends to regard most price movements as somewhat excessive. This is compatible with the rest of the theory of anticipatory prices, even though it does introduce an element of trading that is not immediately motivated by market information. The modification results in a moving average process with four parameters; a negative per cent dispersed over a short span, and a positive per cent dispersed over a longer span. The curve of H-values resulting from this mixed dispersion pattern is approximately the sum of the curves which result from the two dispersions taken separately. The parameter estimates for the mixed dispersion patterns for the two periods are: −6 per cent dispersed over 2 days

[8] Phillipe Berthet and Claude S. Brinegar.

CHART 3.—Comparison of Empirical and Fitted Curves of Index of Continuity



and +20 per cent dispersed over 34 days, for 1922–31, and −10 per cent dispersed over 6 days and +32 per cent dispersed over 52 days, for 1949–58. The actual and fitted curves are tabulated below and shown in Chart 3B:

Interval length	1922–31 Period		1949–58 Period	
	Empirical	Fitted	Empirical	Fitted
2	−.006	−.005	.012	.001
4	−.022	−.023	.008	−.002
8	−.033	−.036	−.007	−.007
16	−.032	−.024	−.003	−.011
32	.005	.010	.030	.015
64	.048	.063	.082	.082
128	.133	.118	.181[a]	.172
256	.148	.156	.253[b]	.256

[a] Significant at 5 per cent level.
[b] Significant at 1 per cent level.

The degrees of freedom are reduced, but the improvement in fit seems to be sufficiently pronounced to warrant the introduction of the more complex pattern of dispersion.

The two periods yield strikingly similar patterns of continuity, and may be combined to yield a single estimate of −8 per cent dispersed over 4 days and +27 per cent dispersed over 45 days. This implies that 81 per cent of the price effect of demand and supply influences occurs on a single day, presumably the day the influences occur and/or the day they become known to the majority of traders in the market. There is then some reaction away from this price movement, even though the initial movement had been insufficient to bring the price to equilibrium. Finally corrective movements occur, resulting in total movement which is just appropriate. If this is a true picture of the operation of the corn futures market, then it approaches very closely the ideal.

We do not yet have a mathematically determined test of goodness of fit, whereby we can evaluate the fit achieved. Other specifications of process might yield an even better fit than is obtained here, though this does not seem very likely. But the most plausible alternative hypothesis—the Taussig theory—can be rejected simply on the basis of the general character of the curve of indexes of continuity.

If the dominant source of price movement were the bounding of price up and down between the edges of a penumbra, the index of continuity should have high positive values at low interval lengths and high negative values at longer interval lengths. If most movements result from over-excited response to minute stimuli and what might be called panicky reactions to previous movements, whether or not consciously manipulated, the index of continuity would have high negative values at *all* interval lengths. Movements of the type Taussig speaks of may occur, occasionally, and the empirical content of the theory consists in saying that these are the dominant sources of movement, or that they occur often enough to have adverse effects on traders and on the resource allocation function of the market. This is disproved by the high *positive* values of the index of continuity at long interval lengths.

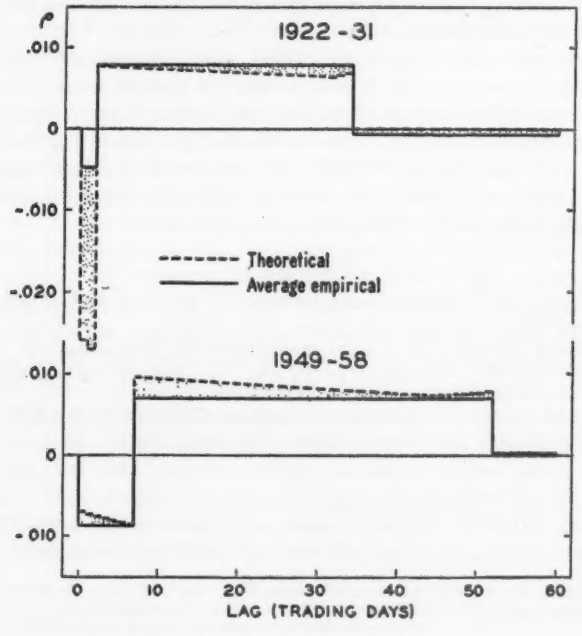
The test of continuity seems to demonstrate the existence of a moving average

stochastic process of the type postulated by Working's theory of anticipatory prices. At the same time it disproves the theory of Taussig and other critics of futures markets. Correlogram analysis failed to do either of these things. We cannot on this account dismiss the correlogram test completely, however. In order that we may accept the moving average process, it is necessary to show that the empirical correlogram is not inconsistent with the theoretical correlogram which is implied by such a process.

Theoretical correlograms for the moving average processes estimated by the index of continuity method were computed for the two 10-year periods. (The negative dispersion span for 1949–58 was increased from 6 days to 7 days in order to include the second large negative correlation coefficient.) The empirical correlation coefficients over the spans so determined were then averaged and the empirical and theoretical correlograms compared. The results are shown in Chart 4. There is one major discrepancy, for the negative dispersion span for the 1922–31 period. Other than that, the agreement is close. This analysis lends further support to the hypothesis that the moving average is the true type of process in operation.

Perhaps an estimating procedure based on the smoothed correlogram could be constructed. Moving average processes of simple types, such as the rectangular, have associated with them correlograms which are also rather simple and reflect the pattern of the weights of the process. Autoregressive processes have correlo-

CHART 4.—Comparison of the Theoretical Correlograms Associated with the Estimated Dispersion Patterns and the Empirical Correlograms Averaged over the Dispersion Spans



grams which are damped oscillatory. The empirical correlogram may have a pattern of one of these types, hidden by random elements which smoothing would eliminate. It is surprising to find virtually no discussion of correlogram smoothing in the literature of time-series analysis, in view of the importance of smoothing in this field. There are hazards in the use of the smoothed correlogram, and there may be insurmountable obstacles, but it is an intriguing possibility.

SUMMARY AND CONCLUSIONS

Analysis based on the index of continuity has demonstrated the existence of a high-order, low-weight moving average stochastic process generating price changes, as envisioned by Working's theory of anticipatory prices. At the same time it has denied the existence of the excessive fluctuation supposed to occur by many critics of futures markets. Autocovariance analysis appeared unable to do either.

These statistical results can be given the economic interpretation that market price changes are closely tied to market news, which tends to be a true reflection of changing demand and supply conditions. But this interpretation rests on the assumption that price can not wander away from equilibrium and remain away for long. For if it could, price movements could be oriented about misinformation or pure guesses, provided only that the misinformation or guesses be random. Taussig and Working both assume that equilibrating forces soon assert themselves, but other critics of futures trading may disagree, and to them much of the argument of this paper may appear tautological. Whatever interpretation one places on the moving average process, it is not to be taken as the only imperfection possible in futures markets.

The potential scope of application of the index of continuity cannot be accurately predicted at this time. It may be that few markets are as near the ideal as are the corn and wheat futures markets, and that any further departure from the ideal introduces factors which will have to be detected and analyzed by other means. On the other hand, the index may prove to be a versatile tool for the analysis of time series from many fields of study, and may be capable of detecting some processes other than the moving average.

CITATIONS

1 F. W. Taussig, "Is Market Price Determinate?" *Quarterly Journal of Economics,* May 1921, pp. 394–411.

2 Holbrook Working, "New Ideas and Methods for Price Research," *Journal of Farm Economics,* Dec. 1956, pp. 1427–36, and "A Theory of Anticipatory Prices," *American Economic Review,* May 1958, pp. 188–99.

3 Arnold B. Larson, "Evidence on the Temporal Dispersion of Price Effects of New Market Information" (diss. Stanford University, Calif., 1960).

Boris C. Swerling

TOWARD POSITIVE POLICIES FOR AMERICAN AGRICULTURE*

How a society deals with its agriculture can be crucial to its economic progress and political structure. Nineteenth century England, in choosing the route of cheap food imports, and Denmark, in subordinating domestic food grains to imported feedstuffs, made decisions affecting the entire course of their future economic development. Despite widespread emphasis on industrialization at the present time, the success of economic programs currently being undertaken in underdeveloped countries will depend in large measure on their handling of the farm sector: their ability to squeeze capital out of agriculture to finance off-farm activities; the extent to which labor can be released from farming for employment in other enterprises; the development of a rural market for the products of local industry; and a high rate of expansion in domestic food supply as a prime offset to domestic inflationary pressures or balance-of-payment difficulties. The Communists exploit legitimate aspirations for land reform, but their longer-term strategy is to destroy an independent peasantry in order to assert political control over the countryside and economic control over the cities. Indeed, Khrushchev has described "the shift of the peasantry to co-operation" as "the crucial problem of socialist development" (6, p. 81).

At home, there are comparable references to the American "farm problem" as the major domestic issue of the day, and it is not at all surprising that the independent farm operator and his counterpart in small business enterprise should enjoy favored treatment in societies that place a high value on private proprietorship. But economic change continually involves advantage to some economic groups and disadvantage to others. Whereas the newly independent countries typically give undue political influence to the town, historical systems of representation in the older democracies seriously overweigh the interests of the countryside. One of the less pleasant manifestations of countervailing power in any democratic society is that an important group whose economic status is deteriorating may exact excessive political conditions as the price of progress. In periods of rapid change, the social challenge is twofold: on the one hand, to resist extravagant claims made in the name of any vested interest, and on the other, to invent instrumentalities that ease the impact of necessary adjustment

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on injured parties without serious damage to the efficiency of the economic system. This is essentially an issue in social justice, and the challenge confronts not only farm policy but also public action in such fields as minerals, tariffs, and depressed areas, to mention only a few.

Artificial market support for individual commodities, which is a distinguishing feature of American farm programs, is the typical means of aiding groups adversely affected by economic change. This commodity emphasis is in line with comparative endowments of economic data, the structure of Congressional committees, and the organization of special interest groups. The commodity approach is in favor among political liberals and conservatives alike. On the one hand, a higher price for wheat or cotton is defended by those whose natural inclination is to favor the disadvantaged. By contrast, among those whose allegiance to private business enterprise is most vociferous, intervention in or even elimination of commodity markets[1] is somehow more respectable than direct income transfers that interfere less arbitrarily with the price system. Similarly, many can argue strongly for states rights and restraint on federal power while endorsing commodity devices for redistributing income among the states. The same people who condemn foreign aid as "giveaways" can vote heavy expenditures for foreign disposal of surplus farm products. It is not too much to say that Congress speaks the language of free enterprise but interferes more extensively with the price system than would be appropriate in a completely socialist state.

Programs for raising farm income by artificially supporting the prices of major crops have relied heavily upon a particular rationale: the apparent unresponsiveness of market demand to changes in prices of agricultural commodities; the short-term inflexibility of agricultural supplies, and particularly the difficulty of reducing total farm output when market prices fall; the vulnerability of primary producers in times of economic depression; and the assumption that federally-organized restriction of farm output would be advantageous to agricultural producers. Respectable econometric investigations can be enlisted in defense of these propositions. The marked contrast between the high professional competence of the agricultural economist and the sordid state of present farm policy does nevertheless lead one to ask whether the failure is entirely one of implementing unchallengeable economic findings, or whether there may also have been serious shortcomings in analysis and prescription. There are certainly other fields of public policy in which the recasting of our economic knowledge, the adaptation of public attitudes, and the adjustment of liberal institutions lag seriously behind the rapid pace at which the structure of modern economic life is changing.

If one is impressed by the malfunctioning of commodity programs, conscious of economic realities that have contributed to recent difficulties, and cool to the merits of policy proposals most widely discussed, he is under some obligation to devise alternative arrangements. May I presume to restate here a different and much more modest approach for protecting the income of farm operators (*11*). The measure attempts to apply standard principles of social insurance, along the following lines:

[1] For a defense of futures trading in onions, see *16*.

1. As with unemployment insurance, benefits would be related to the income experience of the individual farm operator during the recent past.

2. Social security practices would be followed in establishing an upper limit on the amount of insured income, and there would accordingly be a modest ceiling on the total benefits enjoyed by a particular individual.

3. Benefits would accrue only to growers who suffer an abnormal reduction in income, not to prosperous and distressed individuals indiscriminately.

4. Specifically, a grower would draw benefits if his farm earnings in a given year fell more than, say, 25 per cent below the average of the preceding 5 years. The maximum base income would be set at $4,800 net, equivalent to some $15,000 gross.

5. The right to benefits would attach to the person, not to farm land or to the farm enterprise, and would accordingly not be transferable.

6. Benefits would not be conditional upon the production of particular commodities or even upon continued employment in agriculture.

7. Benefits would be scaled downward as off-farm sources of income rose, but at the same time contingent protection would be afforded to persons shifting from farming to other occupations.

8. The plan would be contributory and compulsory, but the federal government would subsidize the program by making premium payments on some matching basis.

The merits and the deficiencies of this particular proposal warrant careful exploration,[2] and this audience is well qualified to evaluate them. But the presentation has the broader purpose of highlighting criteria that any agricultural reform should satisfy under present-day conditions. Let us explore some of the issues the proposal raises.

THE INCOME TARGET

To be sure, the degree of protection afforded would be considerably less generous than is aimed at under present statutory standards. But much frustration has hitherto arisen from the attempt to attain the unattainable. Pursuit of purchasing power parity for agricultural commodities ignores real gains in productive efficiency and human well-being. The goal of an historically-based fair share of the national income for a conglomerate agriculture defies the inevitable decline in that sector's relative position in a progressing economy. Efforts are made to remove the disparity between the absolute level of per-capita income on and off the farm despite the evidence that such differentials are well-nigh universal (*1*), and their meaning is far from clear. Those who stress market development for particular field crops can find little satisfaction in falling per-capita consumption of wheat or potatoes, well demonstrated indicators of dietary improvement. An American Secretary of Agriculture can hardly seek to promote a heavy in-migration to agriculture, an increase in farm population as a percentage of the total, or a steady decline in the average size of farm, but neither can he point with unmitigated pride to trends in a contrary but more appropriate direction.

[2] A recent textbook classifies the proposal among measures for reducing risk and uncertainty (*15*, pp. 489–90). It might equally appropriately be regarded as a direct-payment plan, in which subsidies are paid to offset shortfalls below the farmer's previous earnings rather than upon some alternative basis. (Footnote added 9-26-60.)

Outside agriculture, income-maintenance programs have typically been guided by the principle of a social minimum or have sought to pool risks in order to soften the distress caused by adverse economic developments beyond any individual's control. In this spirit Congress has enacted minimum wage, unemployment insurance, and social-security legislation. Remember that the urban labor force does well if unemployment insurance covers half a man's earnings for a 26-week period, and recall also the considerable number of farm people who now enjoy this degree of protection on the off-farm portion of their earnings. By standards of social insurance, 75 per cent of base represents a generous level of income support, but even higher figures would avoid adverse side-effects that result from corresponding percentages of statutory parity.

THE RELIEF OF REAL DISABILITIES

Confusion and misunderstanding arise from the failure to consider certain alleged disabilities of farm people in proper perspective. The plight of the small-scale farmer is exaggerated if we ignore evidence that rising off-farm earnings appear to have more than offset his reduced earnings from agriculture[8] (7). Mechanization and new technology ought not to be considered as merely independent sources of disturbance, for they have helped agriculture adjust to the drain of labor into the cities (2, p. 272) and have placed a larger scale of enterprise within the competence of a single farm family. Recent trends in farm indebtedness need to be interpreted against the low level of overhead charges attained during the past two decades. The farmer's satisfaction with his current cash position is seriously underestimated unless account is taken both of the rising volume of depreciation charges built into official estimates of net farm income, and also of concurrent changes in the value of his assets.

A more careful identification of the special disadvantages to which farm people are subject and the special disabilities from which they suffer is necessary if we are to specify appropriate fields for public policy. Only a few decades ago, the isolation of the rural hinterland, the immobility of rural people, and the arduousness of farm life and work took high places on the list. Merely to identify the traditional items is to call attention to the considerable degree of success in overcoming them. Electrification and mechanization, much of it internally financed out of farm earnings, have eased hard chores in homestead and fields. The rural electrification program was widely supported, on the principle that a public interest attached to extending transmission lines to sparsely settled rural areas. Farm-to-market roads and an extensive highway network are at least as important for having increased the mobility of farm people, including their access to town jobs and city medical facilities, as they are for having eased the shipment of farm produce. The sweeping changes involved in these improvements in the manner of living are little reflected in official indexes of level of living calculated for farm-operator families.

Income variability—whether the result of natural hazards, changing market circumstances, or special commodity cycles—does remain a real hazard of commercial agriculture, and public policy can reasonably seek to moderate its impact

[8] Operators' combined expenditures for family living and production purposes in 1955 are estimated at $40 billion (*14*), one-third higher than that year's cash receipts from farm marketings and government payments.

upon the individual farmer. Commodity price supports have been discredited in part because they superimposed upon this appropriate objective an excessive income target.

THE CONCERN FOR SOCIAL JUSTICE

The proposal disavows any social responsibility for protecting the market fortunes of higher-income farmers. Clearly the traditional practice of allocating public benefits in strict proportion to volume of marketings does not follow equitable principles of income distribution. Congressional and Administration actions accordingly reflect an increasing inclination to limit total benefits to individual growers. Such ceilings are restraints upon privilege, not upon opportunity. Indeed, under present tax structures and with the high proportion of federal nonmilitary expenditures now absorbed by agricultural programs, it seems likely that price supports involve an essentially regressive redistribution of income. In other respects as well, past programs and present proposals fall short of what social justice would dictate. More attention is paid to bargaining weakness in the markets where farm products are sold than to bargaining strength in the markets where farm labor is hired. Rising wages of farm workers, reflecting improvement in the real well-being of a significant component of the farm labor force, enter the statutory parity ratio as a distinct increase in costs and suggest only deterioration in average farm conditions. Gains to operating farmers are highly transitory if programs defended on grounds of higher income for an underprivileged group serve instead to bid up the price of land and burden succeeding generations of farmers with a higher cost structure. There is a real danger of accentuating this tendency if acreage allotments become freely negotiable or we move to an overt system of marketing certificates. Rights attached to the person are not open to the same criticism.

The relatively large number of low-income farm people has hitherto served to depress per-capita estimates of farm income and has afforded a statistical justification for commodity programs ill-suited to relieving agricultural poverty. Relating benefits to the individual's income experience would be similarly ineffective as an aid for the poor in agriculture; nor can unemployment insurance eliminate urban slums. Yet the insurance route improves the orientation of public policy in two dimensions. In the first place, there can be a frontal attack on the real problems of low-income farm areas, with full recognition of the demographic, regional, and racial factors involved. Secondly, many low-income folk of rural origin are now themselves confronted with unwholesome living conditions in the cities. The public interest in relieving their serious disadvantages of health, training, and community facilities has hardly terminated merely because they have moved to new constituencies. The enormous internal migration of recent decades warrants far more public attention than it has received. Slum clearance can well stand larger public expenditures and commodity programs less if we are to face up to genuine social problems of low-income farm families.

CYCLICAL CONSIDERATIONS

Price supports are commonly regarded as part of our battery of built-in economic stabilizers (*4*), but that view is not entirely justified. The long time lags

that separate announcement of support levels from date of crop harvest, resort to support loans, actual federal expenditures, and subsequent federal receipts from disposal operations are far too long to allow nice adjustment to the requirements of contra-cyclical policy. Study of these processes in the recent past indicates that the consequent pattern of federal spending is as likely to accentuate general economic fluctuations as it is to moderate them (*10*). Heavier call on the agricultural loan programs of the Federal Government during periods of general credit restraint have similarly perverse effects.

The behavior of agriculture, and not just of program instrumentalities, has differed during recent cycles from what we have customarily expected. Consumer spending has been sufficiently maintained that industrial recessions appear to have affected rural America as much by drying up opportunities for off-farm employment as by effects on commodity markets. The traditional view that economic recessions are transmitted in magnified fashion from the general economy to the agricultural sector certainly requires serious reconsideration. With the 1958 demonstration that farm income can rise sharply in the face of industrial weakness, indicators other than the level of general economic activity can best guide the timing of financial aid to farm people. Granted the diversity of income experience within farming during conditions short of major commodity inflation or serious recession, the behavior of the actual earnings of the individual farm operator affords a more serviceable guide for action. Moreover, with production charges now absorbing so large a share of marketing receipts, commodity programs are a particularly expensive method of supporting farm income, and the alternative of overt transfer payments becomes increasingly attractive.[4]

INCENTIVES ON THE FARM

One need not be oversold on the normative virtues of competitive equilibrium and yet be impressed by the usefulness of the price system for coaxing rather than coercing appropriate adjustments. A great failure of the inherited farm program is the perverse inducements it sets before the individual farm operator. Federal aid has been attached to the continued production of unneeded commodities, with heavy emphasis on field crops least associated with a high-consumption society. Marginal incentives to produce have remained high, whereas marginal public returns from surplus output have been exceedingly low. Growers have felt impelled to plant unneeded acreages of surplus crops in order to maintain a production history and insure entitlement to future allotments. High price supports, capitalized into the high value of allotments, required high payments in order to idle land under the acreage reserve program, with the public treasury in effect bidding against itself. The vote by corn farmers to abandon acreage allotments on the 1959 crop was widely advertised as a decision favoring lower prices with more freedom to plant; but a price structure combining higher *average* supports for corn and a 10-point cut in supports on minor feed grains had predictable consequences. Indeed, a price-support structure reflecting the application of various statutory formulas and freezes, percentages of average market price, and sundry lesser criteria, verges on the chaotic.

[4] A curious by-product of present procedures is that the value of agricultural production and accordingly Gross National Product tend to be overstated in the national economic accounts, and a significant transfer payment is completely hidden.

As an instrument of social control, does the resultant price system really serve as well as prices more free to reflect changes in market demand and in real costs? Or could one hope for anything better if various commodity groups were given fuller autonomy in handling their own affairs? One can answer both those questions in the negative without placing farmers' income entirely at the mercy of the free market. Subsidy payments that do not vary directly with output are less likely to distort desirable price signals. An income-insurance plan avoids marginal incentives to expand output, and the contingent assistance it provides ought to have little effect on the grower's decision to plant.

MATTERS OF AGRICULTURAL INPUTS

It is of course widely recognized that farm productivity is increasingly responsive to inputs purchased from outside agriculture. But neither public policy nor economic analysis seems to have taken the implications of this situation into proper account. Public measures for restricting output continue to concentrate on limiting acreage alone; the alternative of limiting use of such highly productive inputs as fertilizer and irrigation water is not seriously considered; and practices that evoke prompt increases in yields are subsidized under cover of legitimate conservation practices. While land-use adjustments as reflected in the Great Plains program may be desirable for their own sake, even a massive program of land retirement does not by itself promise to be an effective route toward production control under present technological conditions.

On the other hand, technical explanations of the "farm problem" in terms of excess labor supply (*5*, p. 47) do not always make it clear that labor outflow cannot reduce surplus capacity if overcompensated by capital inflow. Earlier notions of "capital rationing" were popular during a period of massive capital investment in agriculture (*9*, p. 306). More recent studies of capital intensity in various sectors of the American economy indicate that, if account is taken of factors directly and indirectly employed, a dollar's worth of field crops now absorbs *more* capital relative to labor than do major products of the iron and steel industry (*8*).

Because farmers' propensity to invest is high, programs intended to improve farm levels of living can and do lead instead to higher production expenditures and enlarged surplus capacity. There is certainly evidence that soil bank payments have had precisely that effect.[5] With capital as well as land and labor being devoted to agriculture in excessive amounts, subsidized agricultural credit needs to be disbursed sparingly and judiciously. The legacy of unwarranted investment is of various undesirable sorts: the operator becomes committed to a higher level of cash expenditures in subsequent periods; computed depreciation charges rise, with adverse effects on subsequent estimates of net farm income; and problems of excess capacity are transmitted to agricultural supply industries. Excessive capital formation in agriculture will lead to low returns on farm capital just as surely as high birth rates in rural areas will depress returns to farm labor.

Considerations such as these speak strongly for public measures more likely to have their impact directly on farm consumption and the conditions of family living, including access to medical services, educational facilities, and community

[5] Contrast the behavior of net farm income with that of the monthly index of value of shipments of farm machinery, equipment, and wheel-type tractors (*13*).

services generally. Income payments that offset shortfalls in earnings seem far less likely to be dissipated in production expenditures than are the windfall gains, unrestricted in total amount, that frequently accrue under existing programs.

EFFICIENCY OF ADMINISTRATIVE CONTROL

Present programs frequently make impossible claims upon the administrative capabilities of the responsible agencies. This occurs when major activities must be initiated too quickly, like the acreage reserve program in 1956; or when enforcement regulations are deemed too onerous, as in the fight against cross-compliance; or when there are few standards that can be unequivocally applied, as in various disaster relief measures. Considering the vested interests already built into the purchasing, lending, storage, exporting, and importing functions of the Commodity Credit Corporation, and the enormous volume of its business, the surprise is that outright administrative bungles are so infrequent. Program minutiae involving individual agricultural commodities continue to absorb an exhausting amount of Congressional energy, long after experience has dictated a less intimate role in such fields as tariff-making and public-utility regulation. The time pattern of Congressional action is at odds with biological lags in agricultural production, and the farm operator cannot know what rules of the game are to be enforced in the period ahead. Whatever reduction may have been made in the degree of economic uncertainty confronting farmers has been offset, in part if not entirely, by rising political uncertainties.

Whether a system of tight marketing controls could be effectively administered remains seriously in doubt, and the higher the price target, the larger will enforcement problems loom. Marketing agreements have hitherto succeeded where the pattern of supply closely approximated conditions of natural monopoly, which is hardly the case for major field crops. The sugar program, frequently cited as a prototype, is facilitated by special relationships between individual growers and a limited number of processors, and the administrative record would be far less satisfactory if foreign sugar supplies did not provide a buffer for the entire control system.[6] Even a strong advocate of marketing controls is impressed by the difficulty of regulating the feed-grain sector (*3*, p. 353).

Before the extension of social security to farm operators, it would have been quite impractical to suggest initiating a system of income reporting for purposes outlined in this paper. But with comprehensive administrative machinery now in existence, new alternatives are open. Administrative standards are certainly more solidly established for social insurance than for price supports, and income insurance has features that provide a high degree of self-policing against possible abuse. There is good reason to believe that scales of premiums and benefits could be devised that would be quite as defensible as those now in use for purposes of unemployment insurance and social security itself.

INTERNATIONAL COMMODITY POLICY

An incidental gain from going the income-insurance route is that here is one approach that may be applied also to the international instability problems of

[6] Deteriorating Cuban-American relations have now seriously undermined, if they have not completely eroded, the basic arrangements upon which an efficient sugar program has been built. (Footnote added 10-18-60.)

primary-producing countries (*12*, p. 128). Consistency between our foreign and domestic practice would be a welcome change from the present state of affairs. Parity between prices paid and received by farmers remains the domestic standard, but at the water's edge we renounce the terms-of-trade approach to stabilizing price relationships between primary products and manufactured goods. We are prepared to dispose of surplus stocks of imported rubber on an announced schedule, but there is little inclination to do likewise with domestic corn or wheat. We endorse historical share of world markets as a rule applicable to cotton but would be considerably embarrassed if it were extended to American exports of soybeans, corn, or inedible animal fats. Stocks of wheat and corn on hand are to some degree justified as contingency reserves, but official concern does not extend to the size of mainland stocks of sugar or coffee, the two major foodstuffs shipped in by ocean-going vessels. International commodity agreements are resisted for imported commodities subject to cyclical instability in industrial demand, but are endorsed for an export commodity like wheat and also for an imported one like sugar, lest lower world-market prices embarrass our domestic control programs. Commodity measures make for difficulties in our trade relations with countries whose political values and economic institutions most closely resemble our own. Here are further good reasons for aiding farm people otherwise than by the commodity route.

CONCLUDING REMARKS

A few concluding comments are in order. The professional economist concerned with agriculture, like his colleague in the monetary field, is fortunate in the abundance of empirical data at his disposal, and society enjoys a certain corresponding immunity from irrelevant flights of academic fantasy. It is upon close observation of economic events, rather than upon the customary expertise of the agricultural economist, that many of the judgments in this paper are based. The discussion does not lead to a full-scale prescription for public policy, an agenda for the research worker, or a program for the extension service, and perhaps the path of advocacy has been pursued beyond the limits of good scholarship.

Whatever the defects of the precise mechanism here outlined, it does meet the challenge to devise institutional arrangements appropriate to present-day circumstances. The exercise of ingenuity is far more respectable in fields like mathematics and technology than in the area of social institutions; and it is easier to prescribe institutional reforms for the agriculture of underdeveloped lands abroad than to cast off discredited agricultural policies at home. Upon America's capacity to adapt domestic social arrangements in keeping with contemporary needs and in the spirit of Western liberalism, much depends.

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THE NATURE OF AGRICULTURE'S CONTRIBUTIONS TO ECONOMIC DEVELOPMENT†

I. INTRODUCTION

In the burgeoning literature on economic development there has been considerable discussion of the relative importance of agricultural vs. industrial development. Few attempts have been made, however, to examine in detail the nature of agriculture's contributions to the process of economic growth. In particular, it seems desirable to consider more fully the inter-relationships between agricultural and industrial expansion and the extent to which agricultural development is complementary to over-all economic growth.

Expansion of agricultural output requires increased inputs, and in that sense necessarily competes with other sectors of the economy. Historical experience and theoretical considerations suggest, however, that the optimum approach to increasing farm output and productivity in an underdeveloped country is likely to entail only modest demands on the critically scarce resources indispensable for industrial development.

Since the emphasis in the present paper is on the nature of agriculture's contributions to economic advance, only a brief statement is given here of the reasons underlying the assertion that farm output and productivity can and should be increased by methods that make very limited demands on resources of high opportunity cost which are essential for industrial expansion.[1] In virtually all underdeveloped economies agriculture is an existing industry of major proportions. On the order of 40 to 60 per cent of the national income is produced in agriculture, and some 50 to 80 per cent of the labor force is engaged in agricultural production (*11*, pp. 94–97, 193; *26*, pp. 45–47). Although large quantities

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† An attempt to present a general statement of agriculture's contributions to economic development is a hazardous undertaking. If we have succeeded in making a contribution to consideration of this complex and important question, it is largely due to the valuable criticism and suggestions that have been directed at successive drafts of this paper. Discussion of early versions of the article with David Bell, W. Arthur Lewis, Kazushi Ohkawa, William O. Jones, and Helen C. Farnsworth was especially valuable in clarifying our ideas and organization. We are indebted to M. K. Bennett for his final editing of the manuscript which has added clarity and led to needed qualification of some of our generalizations. The authors are, of course, solely responsible for the faults that remain.

[1] The argument is sketched in an earlier article on "Agricultural Productivity and Economic Development in Japan" (*21*) and is presented in more detail in a paper on "Agricultural Development and Economic Transformation: Japan, Taiwan, and Denmark" (*20*).

of labor and land are committed to agriculture, these resources are being used at low levels of productivity. Frequently, the amounts of available capital in the form of draft animals and small tools and equipment are also substantial relative to the total stock of capital. The low levels of productivity that characterize the use of resources currently available in agriculture is due largely to the lack of certain complementary inputs of a technical, educational, and institutional nature.

Under these circumstances, though more in densely than in sparsely populated regions, the most practical and economical approach to increasing farm output and productivity lies in enhancing the efficiency of the existing agricultural economy by introducing various technological innovations within the framework of the existing labor-intensive methods of production and with a minimum of capital investment. The large quantities of land and labor already being used in agriculture are characterized by low opportunity cost. There are obviously strict limits on the extent to which available agricultural land resources can be used to further industrial development. Agricultural labor can, in general, be expected to have low opportunity cost for some time since lack of capital prevents rapid absorption of labor by the expanding non-agricultural sectors. This argument is based in part on the validity of Engel's Law interpreted in relation to the increase of incomes over time. Since the demand for food does not rise as rapidly as the growth of income, the demand for the aggregate of goods and services produced by the non-agricultural sectors of the economy expands more rapidly than the increase in demand for agricultural products. Historically, a secular decline of the agricultural sector seems to have been a universal feature of the process of economic growth at least beyond the earliest stages. The essential characteristics of this phenomenon have been summarized succinctly by Kuznets: "when modern economic growth does occur, it is the combination of the marked rise in productivity of labor in the agricultural sector, with the secular limits on the demand for its products that results in such a sharp and uniform reduction of the agricultural sector in the labor force" (*26*, p. 60).

The historical experience of Japan and Taiwan, to mention two interesting and pertinent examples, demonstrates the substantial potential that exists for raising farm output and productivity by techniques that rely mainly on the use of resources that have low opportunity cost. Agricultural development in these countries made only minimal demands on the critically scarce resources such as investible funds, foreign exchange, and high calibre entrepreneurial talent which are indispensable for industrial development.

Labor productivity in Japanese agriculture seems to have approximately doubled over a span of thirty years, comparing farm output and labor inputs during the years 1881–90 with the decade 1911–20. Studies of agricultural change during that period indicate very clearly that the overwhelmingly important factors responsible for the growth in productivity were: (1) agricultural research leading to the development and selection of higher-yielding varieties of rice and other major crops; (2) increased application of fertilizers; and (3) activities that facilitated wide use of the most productive plant varieties and of improved farm practices. There was little change in the organization or cost structure of Japan's agriculture during this period; cash and other non-labor costs were some 15 per cent of the gross value of production at the beginning of the period, and were still only about 20 per cent at the end (*21*, pp. 498–513; *34*; and *20*).

The increase of labor productivity in agriculture in Taiwan was even larger—something like 130 to 160 per cent over the 30-year span between the decade 1901–10 and the 1930's.[2] Here also the gains in productivity were largely the result of technological advance. An extraordinary threefold expansion of sugar yields and nearly a twelvefold increase of output were conspicuous elements in the increase in agricultural productivity registered in Taiwan. It will be recalled that this was primarily an export crop and that the first three or four decades of the present century were a period of spectacular progress in breeding higher-yielding varieties of sugar cane; particularly noteworthy were the POJ varieties developed in Java but shortly introduced in Taiwan. Increase of crop area, largely through extending the area of double cropping, and expansion of irrigation appear to have been more important in Taiwan than in Japan during the periods considered; development in those directions in Japan was already fairly advanced by the 1880's (*40*, pp. 95–97). Agricultural investment thus appears to have been a somewhat more important factor in Taiwan than in Japan, but to a large extent it was direct, non-monetary investment (*20*).

The expenditures for agricultural research, extension-type activities, and other "developmental services" that were of such strategic importance in Japan and Taiwan were very modest, particularly in relation to the large increments in output that were attained. The conclusion is inescapable that the returns accruing to this type of investment were exceedingly high. Outlays for fertilizer increased rapidly and were substantial. This represented a resource demand that was competitive with industrial expansion since it required foreign exchange and, in the case of Japan, the erection of fertilizer plants. But the returns obtainable were very large relative to the cost of the additional fertilizer inputs. There is, in general, a high degree of complementarity among various agricultural inputs, and fertilizers are a conspicuous example. The work of the plant breeders in Japan and Taiwan was largely directed at developing varieties characterized by a strong response to increased applications of fertilizer; the gains achieved were the result of the joint advance in varietal improvement and in raising the level of soil fertility. Changes in cultural practices, such as an increase in plant density, were also needed to realize the full potential of new varieties.

The implications of the secular decline of agriculture and the process of economic transformation are examined further in section III in considering agriculture's role in relation to capital formation. It is well to anticipate, however, that the distinction between resources of high and low opportunity cost that has been stressed is most clearly applicable and significant in countries of high rural population density, such as Java, India, or Egypt. In the concluding section, brief consideration is given to the extent to which the argument requires modification in relation to the extensive areas of tropical Africa and South America where rural populations are sparse.

[2] This estimate is based on an index of physical output in calorie equivalent described in *20*. Shifts from low- to high-value crops (or vice versa) were relatively unimportant in Taiwan during this period, and there appears to have been only a modest change in the relationship between gross and net value of farm output. Hence, it seems reasonable to suppose that the increase in value productivity was also on the order of 130 to 160 per cent. In Japan, the increase in labor productivity in agriculture between 1881–90 and 1911–20 was a little over 100 per cent on the basis of estimates of the net income produced in agriculture and a little less than 100 per cent according to the increase in physical output (*20*).

II. THE GROWTH OF DEMAND FOR AGRICULTURAL PRODUCTS

The most obvious contribution of agriculture to economic development is in providing the enlarged supplies required to satisfy the rising demand for food. The prime determinants of this growth in demand are the rates of increase in population and in per capita incomes. Only a part of higher incomes will be devoted to expenditure on food, so the influence of a rise in per capita incomes depends on the income elasticity, which for present purposes can be defined simply as the proportionate increase in demand for food associated with a one per cent increase in income. The annual rate of increase in demand is thus given by $D = p + \eta g$, where p and g are the rate of growth of population and per capita income and η is the income elasticity of demand for agricultural products (*32*).[8] Demand in this instance refers to the (real) value of food purchased plus the reservation demand for items produced by a family for its own consumption, an element that may be of some importance even for urban residents in underdeveloped countries. Among the factors other than growth of population and per capita incomes that may influence the demand for food, changes in consumer preferences may be of appreciable importance where population groups are becoming familiar with new foods; the rise in bread consumption in tropical Africa, for example, seems to be a function of urbanization and acculturation as well as a rise in incomes *per se*.

Population growth.—One of the striking uniformities in the modernization of a country is the population upsurge that occurs when death rates fall from perhaps 35 to 45 per thousand toward the level of about 10 per thousand which characterizes the economically advanced nations. This decline is mainly a result of improved sanitation, public health measures to control infectious diseases, general improvements in medical care, and improvements in nutrition and midwifery. At present, international borrowing of knowledge and techniques in the public health field is so important that there is only a weak relationship between the spread of these measures and growth of per capita income. Moreover, the decline in mortality is often both substantial and abrupt, owing to recent discoveries such as DDT, the sulpha drugs, and penicillin, which have markedly increased the effectiveness of public health and sanitation measures. Without exception, birth rates have fallen much more slowly than death rates. Apart from the exceptionally high rate of growth in the United States, where immigration was an important factor, none of the presently developed countries witnessed annual rates of growth in excess of 1.4 per cent (*10*, p. 2). Taiwan showed the effects of widespread and systematic introduction of public health measures at an unusually early date, the rate of natural increase rising above 2 per cent during the 1920's (*2*, p. 13). Ceylon perhaps is the most conspicuous example of rapid reduction in death rates. Largely as a result of the control of malaria, mortality fell from 19.8 per thousand in 1946 to below 10 in 1956; and since birth rates declined much less, the rate of natural increase rose from not quite 2 per cent to 2.6 per cent in a decade. Since the end of World War II it has become increasingly common for rates of population growth of 1½ to 2½ or even 3 per cent to characterize a developing economy.

[8] The equation omits a second order term that is of negligible importance, particularly in view of the margin of uncertainty that necessarily characterizes estimates of income elasticity and rates of increase of population and income.

Income elasticity of demand for food.—The increase in demand for food in response to the growth of income in underdeveloped countries is significantly higher than in the economically advanced nations. Examination of the evidence bearing on the income elasticity of demand for food in underdeveloped countries, as measured by value, suggests that it is on the order of 0.6 or higher, compared with figures of perhaps 0.2 or 0.3 in high-income nations. These approximations relate to income elasticity with respect to food expenditure measured at the farm level, the concept most relevant to assessing the growth of demand for agricultural products.[4] Precision cannot be claimed for these figures because of the various difficulties involved in estimating income elasticity of demand even in countries where statistical data are of high quality and abundant. Knowledge of secular trends in food consumption and of differences in diet patterns between high- and low-income countries provides strong collateral evidence for the assertion that the income elasticity of demand for food is much higher in the low-income countries.

The increase in food expenditure with growth of income, not only in developed but also in underdeveloped countries, is mainly a result of shifts from less to more expensive foods rather than increased intake of food calories.[5] The rise in consumer outlays for food in underdeveloped countries is partly a result of substitution of more expensive but preferred starchy staples such as rice and wheat for cheaper foods such as maize or millets and sorghums. To a greater extent, however, it is likely to reflect a decline in the "starchy staple ratio," i.e., the percentage of total calories derived from cereals and root crops which M. K. Bennett has shown to be closely correlated with the level of national income (*3*, pp. 213–22; see also *14*, pp. 214–15, and *12*, pp. 244–47). In low-income countries these cheap starchy foods provide from 60 to 85 per cent of the total calorie intake, in contrast with a level of 25 to 40 per cent in economically advanced countries where the starchy staples have been displaced by increased consumption of the more expensive foods with relatively high income elasticities—meat and dairy

[4] Inter-country comparisons of income elasticity based on cross-section data are presented in *14* and *19*. Also suggestive is the fact that the estimated income elasticity of demand for edible agricultural products in Japan, based on time series data, declined from 0.6 for the period 1878–1921 to 0.2 for the years 1922–37 (*31*, p. 122). Estimates of income elasticity of food expenditure in India are summarized in *8*, pp. 124–27. The high figures for the United States, above 0.6, obtained by Houthakker on the basis of cross-section data from the 1950 urban consumption surveys are puzzling. They are certainly not indicative of the income elasticity of demand for the farm-produced component of food purchases. Miss Burk has estimated the income elasticity of demand for food in the United States at about 0.2 for the periods 1924–41 and 1948–57, using both a farm value-weighted index (farm-produced foods only) and a retail value-weighted index (consumption of all food). Using a "structural index" based on cross-section data for consumption at home from the 1955 Survey of Household Food Consumption, but using farm commodity equivalents and farm prices, she estimates the income elasticity for all urbanization categories at 0.12 for "use of farm foods—all sources" and 0.24 for purchased food only (*5*). Daly has estimated the income elasticity of demand for food at the farm level in the United States at less than 0.15, using time series data but a different technique (*9*). Marketing and processing services account for about 60 per cent of the retail value of foods purchased in the United States. Correlation between income level and the services component produces an upward bias in estimates of income elasticity based on cross-section data for the United States (unless adjusted as in Miss Burk's computation). This factor is undoubtedly much less important in cross-section estimates for underdeveloped countries since the processing, packaging, and marketing components incorporated in the foods purchased at retail are relatively insignificant; the services are less elaborate and wage costs much lower.

[5] A very crude indication of the income elasticity of demand for food with respect to quantity measured in calories is provided by inter-country comparisons of per capita calorie intake in relation to income. By this approach the FAO has estimated that the income elasticity of demand for calories is 0.1 or less except for countries near the bottom of the income scale (*14*, pp. 88–89).

products and fruits and vegetables.[6] Since the starchy staple ratio in high-income countries is already low there is less scope and urge to shift from cheap foodstuffs toward more expensive sources of food calories.

Inflationary impact of food shortages.—The annual rate of increase of demand for food in an underdeveloped country can easily exceed 3 per cent, a formidable rate of growth in agricultural output to be achieved by an underdeveloped country.[7] The annual increase in net agricultural output in Japan between the 1880's and the decade 1911–20 appears to have been only about 2 per cent; this was the period of most rapid increase in agricultural production, and Japan is cited with good reason as a country in which an impressive increase in agricultural productivity made a significant contribution to over-all economic growth. It is also to be noted that the growth of demand for marketed supplies will be a good deal more rapid than the total increase, owing to the increase of population in cities and mining and industrial centers dependent upon purchased food.

Failure to expand food supplies in pace with the growth of demand can seriously impede economic growth. Professor Lewis takes such a serious view of the adverse effects on economic development of food shortages and rising prices that he has asserted that "failure of peasant agriculture to increase its productivity has probably been the chief reason holding down the expansion of the industrial sector in most of the underdeveloped countries of the world" (*28*, p. 23). It is, of course, debatable whether a stagnant agricultural sector has been the most important single factor, but there are compelling reasons why insufficient expansions of farm output is likely to lead to a rise in food prices and act as a brake on economic development.

Very little evidence is at hand concerning the responsiveness of the demand for food to a change in food prices in underdeveloped countries. The price elasticity of demand for individual foodstuffs is probably higher than in economically advanced countries. At least with important items, the pressure to substitute is strong when relative prices change.[8] With respect to the price elasticity of demand for "all food" there is a presumption that the reverse is true, at least in the case of an increase in food prices. Since cheap starchy staple foods—cereals and root crops—provide something like 60 to 85 per cent of the total calorie intake in low-income countries, there is relatively limited scope for offsetting a rise in food prices by shifting from expensive to less costly foods. There is obviously no substitute for calories. Because of the pressure to resist a reduction in calorie intake, it seems likely that the price elasticity with respect to the total amount of food demanded is close to 0.

The inflationary impact of a rise in food prices is particularly severe in un-

[6] Meat and dairy products are inherently more expensive than the starchy staples; the agricultural resources required to produce 1,000 calories are substantially greater because of the large loss of "primary calories" when grain or root crops are fed to animals instead of being used for direct human consumption. The high water content and perishability of fruits and vegetables make them costly sources of food calories. Sugar and fats, which have also tended to displace starchy staples, are not necessarily more expensive sources of calories.

[7] Rates of increase of population and per capita incomes of 2 per cent per annum and an income elasticity of 0.6 give a value of 3.2 per cent for D in Ohkawa's demand equation.

[8] See, for example, one instance that has been summarized by W. O. Jones (*22*, pp. 117–19). Sharp increases in the prices of staple foods other than maize (which was subject to government controls) led to drastic changes in the importance of different staples in the diets of workers in Kampala, Uganda between September 1952 and September of the following year.

derdeveloped countries because food purchases bulk so large in total household expenditures. Urban budget studies in a number of underdeveloped countries indicate that on the order of 50–60 per cent of total consumption expenditure is devoted to food compared with 20 to 30 per cent in the high-income countries.[9] Exceedingly low price elasticity of demand for food, together with its dominant position as a wage good in underdeveloped countries, means that even a moderate growth of demand ahead of supply will cause sharp price rises leading to political discontent and pressure on wage rates with consequent adverse effects on industrial profits, investment, and economic growth.

Since the economic and political repercussions of a considerable rise in food prices are so unfavorable, domestic food shortages are likely to be countered by expanded food imports to the extent that foreign exchange or credits are available. Even if this response is restricted by import or foreign exchange controls, political pressures will be strong to provide sufficient food imports to hold down food prices. It is, of course, reasonable to rely on imports to even out fluctuations in domestic supplies; and in some instances it may be economic even as a long-term policy to follow the pattern of Britain in the period since repeal of the Corn Laws and obtain enlarged food supplies largely through expanded food imports. This solution is obviously not possible on a world-wide basis, and there are considerations that suggest that for many countries it is likely to be a questionable solution.

Foreign exchange is usually a critically scarce resource required for imports of machinery and other requisites for industrial development that cannot be produced domestically; and demand for such items can be expected to increase as development proceeds. "The real choice," as Chenery has expressed it, "is then between expanding exports and expanding production for home consumption" (*7*, p. 67).[10] This problem of "import substitution" is a difficult one because it is unlikely that the comparative advantage of imports vs. domestic production in the future is accurately indicated by a comparison of present prices translated at the existing exchange rate. These considerations clearly do not justify the adoption of autarchic policies with respect to food imports. But recognition of the critical and increasing need for foreign exchange, and the difficulties likely to be encountered in expanding exports, underscores the potentially high returns to measures to increase agricultural productivity and output, especially when this can be achieved largely through the use of resources of low opportunity cost. This is a presumption, not a certainty. It does not alter the fact that there are cogent reasons for maintaining price competition between domestic and imported foodstuffs, and it is frequently advantageous to import certain foodstuffs which cannot be produced efficiently, wheat in tropical regions being an important example. For some underdeveloped countries with very limited tax resources, it is arguable that a duty should be levied for revenue purposes on certain

[9] The unweighted arithmetic average of food expenditure as a percentage of total expenditure according to budget surveys in 20 African cities is 63 per cent. Estimates based on the Fourth Round of the National Sample Survey in India (1952) indicates that 55 per cent of total household expenditure in urban areas and 67 per cent in rural areas is devoted to food (*8*, p. 125; see also *11*, pp. 101–102 and p. 194).

[10] To the extent that United States agricultural surpluses are made available on favorable terms the statement calls for qualification, India being a conspicuous case in point. There remains, however, a question whether such windfall supplies will be available on a continuing basis.

imported foods with consequent biasing of the structure of relative prices in favor of local products.

A number of underdeveloped countries have reacted to the social and economic problems resulting from food shortages and high prices by instituting price controls, compulsory food collection, and rationing. It is understandable that considerations of social equity would prompt such action in a low-income country, but from the standpoint of economic development the consequences of continuing food distribution controls for an extended period are almost entirely unfavorable. In the first place, to the extent that food rationing and price controls are effective, they simply transfer the pressure resulting from increased purchasing power to other parts of the economy or toward imports, so that the inflationary impact impinges on resources that are scarcer than those required for expanded agricultural output. Moreover, the effort to operate such controls ties up administrators and agricultural specialists in a control function that is not only of uncertain value but usually ineffective as well. Even in relation to the interests of the lowest-income groups that are theoretically benefited most by a program of direct controls, it seems certain that much higher returns can be obtained by using the available administrative talent for a well conceived program of agricultural development directed at increasing output rather than controlling its distribution. It is also important to note that distribution controls frequently impede the growth of a commercially oriented agriculture and discourage expansion of specialized production in areas of high potential (*39*, pp. 121–26).

Export and industrial crops.—Particularly in the early stages of economic growth, the development or expansion of agricultural exports is likely to be a relatively easy and economical means of increasing incomes and augmenting foreign exchange earnings. Similarly, some of the early and most promising opportunities for expanding manufacturing lie in textiles, the crushing of oilseeds, and other industries that depend upon agricultural raw materials.

A profitable export crop can often be fitted into an existing cropping system; the capital requirements for such innovations are relatively modest and depend to a considerable extent on direct, non-monetary investment by farmers. Given favorable natural conditions and political stability, it is possible to attract foreign investment for plantation production of agricultural export crops that are demanding in their requirements for technology and capital. There is a reasonable expectation that the new crops and techniques will come to be adopted by local cultivators; the growth of production of rubber by small holders in Malaya and Indonesia is pertinent (*44*, pp. 76–79). Development of production of export crops has the further advantage of catering to an existing market. Even though aggregate demand for many agricultural exports is inelastic, an individual country that accounts for only a fraction of world exports faces a fairly elastic demand schedule, considerably more elastic than the demand for food crops for the domestic market. Hence, substantial expansion of export production is often a rational policy even though the world supply-demand situation for a commodity may be unfavorable. There is, of course, the risk that substantial expansion of exports of a commodity in a number of countries may lead to a serious decline in the price of a primary commodity for which the price and income elasticities are low.

It is well known that export crops have frequently been important in generating increased incomes and foreign exchange earnings. Uganda may be cited as an extreme example; exports of coffee and cotton account for some 85 per cent of the value of all exports and, still more striking, close to 50 per cent of the country's cash income. This is extreme, but examples of considerable dependence on agricultural exports can be easily multiplied. Wickizer has summarized export data for eight important tropical crops for the years 1955–57; for five out of eight, the leading exporter depends on a single crop for more than 50 per cent of its foreign exchange earnings (*44*, p. 56):

Commodity	Leading exporter	Per cent of country's exports by value
Sugar	Cuba	71
Bananas	Ecuador	53
Cocoa	Ghana	64
Coffee	Brazil	63
Rubber	Malaya-Singapore	53

Heavy reliance on export proceeds from one or a few crops obviously makes an economy vulnerable to fluctuations in world prices, but opportunities for diversification are likely to be meagre for a country at an early stage of development. To a considerable extent the flexibility of a diversified economy is one of the rewards of development. For this and for more basic reasons, it is argued in section III that a transformation of the occupational and output structure of an economy is an essential condition for self-sustaining, cumulative development. Of more immediate importance, however, is the fact that the expansion of incomes and foreign exchange earnings by introducing or enlarging the production of promising export crops can and should play a strategic role in promoting economic growth in many underdeveloped countries.

Increased food supplies and health and productivity.—Knowledge of food intake and of human nutritional requirements is too imprecise to permit accurate assessment of the extent or seriousness of malnutrition or calorie shortage in underdeveloped countries. Global claims that "malnutrition and actual hunger is the lot of at least two-thirds of mankind" cannot be supported by evidence.[11] Study of a considerable number of nutritional surveys of sample population groups, the most reliable type of evidence available, suggests that both calorie shortage and serious malnutrition are limited to a relatively small though appreciable fraction of the world's population. The marked differences in conditions in different countries, and regions within a country, cast strong doubt on broad generalizations with respect to nutritional status. According to our reading of the available evidence—admittedly incomplete and often difficult to interpret—it would be a mistake to expect the widespread and substantial improvement in productivity as a result of improved diets that is sometimes claimed. It is not denied, however, that in a good many areas significant gains in health can be expected; the contribution of improved nutrition to the lowering of infant mortality rates is likely to be especially notable.

[11] The quoted phrase is from Lord John Boyd-Orr (*4*, p. 11). See Bennett's appraisal of Orr's assertion (*3*, pp. 189–200) and the discussion by Farnsworth (*15*, pp. 4–11). The articles by Scrimshaw (*38*) and Hegsted (*17*) are good, brief statements by competent nutritionists with experience in underdeveloped regions.

In some of the underdeveloped regions there are rural groups with a pattern of life characterized by spasmodic bouts of intensive work followed by prolonged periods of very low activity. Calorie intake is low when physical activity is low, and participation in a modern money economy involving sustained work means an increase in calorie requirements. Of more general nutritional significance is the enlarged consumption of vegetables and fruits, meat, and dairy products that generally results from an increase in per capita incomes. These commodities are often termed "protective foods" since they are good sources of the vitamins and high-quality protein that are not generously provided by a diet consisting predominantly of the starchy staple foods.[12]

On the other hand, rising incomes and the process of urbanization typically lead to other dietary changes that represent deterioration from the nutritional point of view. A shift toward consumption of more highly milled grain products means reduced availability of the B vitamins; and higher consumption of sugar and soft drinks is at the expense of foods that provide essential nutrients as well as calories. The shift from native beer or wine to commercial beer or spirits means a loss of vitamin C and the B vitamins that are available in significant quantities in the unfiltered traditional beverages.

The changes in diet composition that represent improvement in nutritional quality are likely to be more important, but this is neither certain nor universal. Attention to nutritional education and measures such as encouraging or requiring parboiling or under-milling of rice and enrichment of wheat flour may be equally important, especially as short-term measures.

III. AGRICULTURE IN RELATION TO CAPITAL FORMATION

It is widely recognized that the process of economic development involves a transformation of the structure of an economy such that agriculture accounts for a diminishing share of national income and the labor force. A closely related requirement for development is not so generally recognized. For reasons developed in this section, it is likely to be essential for agriculture to make a net contribution to the capital requirements for industrial expansion and for overhead investment, especially during the earlier stages of economic growth.

Secular decline of agriculture and economic transformation.—Economic development is a complex process that has revealed many different historical patterns. Nevertheless, secular decline in the relative importance of the agricultural sector has been a universal feature of economic development defined as substantial improvement in per capita income levels. Dovring's analysis of long-term changes in the composition of the labor force in a number of countries indicates that there has normally been an increase in the absolute numbers employed in agriculture during the early phase of industrialization, but a decline in absolute

[12] Many nutritionists regard insufficient protein intake—in quantity and quality—as the most pervasive nutritional problem in underdeveloped countries. Meat and dairy products provide protein of excellent quality; but a protein intake of good quality can also be obtained, and at considerably lower cost, from a suitable combination of vegetable foods, soybeans, peanuts, and other legumes being especially valuable in supplementing cereal proteins (see *13*, pp. 21–31). Josué de Castro claims that a diet high in animal protein contributes to low fertility; but nearly all professional nutritionists would concur in the view expressed by Ancel Keys that de Castro's argument (that chronic hunger, particularly hunger for protein, increases sexual drives and birth rates) "is replete with error" and "simply not defensible" (*24*, pp. 38–39).

as well as relative numbers at a later stage (*10*). This is to be expected, he notes, on the basis of a simple mathematical relationship. The rate of increase in the percentage share of non-agricultural employment in the total labor force of a country will be equal to the difference between the growth rates of the non-agricultural labor force and the total labor force. Although this difference, which Dovring terms the "coefficient of differential growth," determines the rate of change in sector proportions, the numerical reduction of the agricultural labor force will also depend on how heavily the non-agricultural sector weighs in the total labor force. Thus, as he points out, a coefficient of differential growth of 1 per cent (associated, for example, with an increase in the non-agricultural labor force of 3 per cent per annum and a 2 per cent rate of increase in total labor force) might mean an increase in non-agricultural employment from 20 to 20.2 per cent at an early stage of development but an increase of from 50 to 50.5 per cent in a country where non-agricultural employment already accounted for a substantial share of the labor force.

What are the reasons for this structural transformation of a developing economy? The two most basic factors have already been mentioned: (1) an income elasticity of demand for food considerably less than one, and (2) the scope that exists for increasing agricultural productivity which permits substantial expansion of output with a constant or declining farm labor force.[13] "Put in its simplest terms, the crux of the problem is this: In a country with a highly productive agriculture each farm family produces enough to feed itself and some ten to twenty non-farm families as well. But if this is to be possible there must be ten to twenty non-farm families to feed" (*11*, p. 126).

Since production for export caters to a world market it is to be expected that the relative decline of the agricultural sector will not proceed as rapidly or as far in countries that have a marked comparative advantage in the exportation of agricultural products. It was emphasized in section II that enlarged exports of farm products often make a positive contribution to development in generating increased incomes and foreign exchange earnings. It is important to recognize, however, that even countries particularly well suited by their resource endowment and historical circumstances to emerge as major agricultural exporters can be expected to witness a decline in the relative and, eventually, absolute share of agriculture if they achieve a substantial increase in the level of per capita income. In Denmark and New Zealand, conspicuous examples of countries that have benefited greatly from their role as leading agricultural exporters, less than 20 per cent of the labor force is presently engaged in agriculture. Thus historical experience, as well as some of the inter-relationships considered below, seems to indicate that cumulative economic growth requires expansion of manufacturing and other components of the non-agricultural sector, not merely a change in the product mix available for consumption which might be obtainable up to a point by means of international trade.

The two-sector classical growth model.—The inter-relationships between agriculture and general economic growth can be brought out most clearly in terms

[13] In addition to the various editions of Colin Clark's *Conditions of Economic Progress*, see E. M. Ojala, *Agriculture and Economic Progress* (London, 1952); T. W. Schultz, *The Economic Organization of Agriculture* (New York, 1953); and M. Latil, *L'évolution du Revenu Agricole* (Paris, 1956).

of Professor Lewis's version of the classical growth model which assumes that there is a surplus of manpower in agriculture; and the non-agricultural sectors are regarded as the dynamic element which absorbs this surplus of manpower. More precisely, the distinction made in this two-sector model is not between agriculture and non-agriculture but between a "subsistence" or "traditional" sector and a "capitalist" sector. The capitalist sector is defined as "the sector of the economy where labour is employed for wages for profit-making purposes," and it is further characterized by the use of reproducible capital (*28*, p. 8; *27*, p. 146). The balance of the economy comprises the traditional or subsistence sector which is using virtually no reproducible capital and is characterized by very low output per head.

Since the supply of labor available in this traditional sector is assumed to be effectively "unlimited," the transfer of manpower to the capitalist sector is limited by the demand for labor which in turn is limited by the rate of capital accumulation. Shortages of skilled labor may, of course, be a serious problem in a developing economy, but it is only a "quasi-bottleneck" in the sense that it can be dealt with if funds are available for training programs. The real bottlenecks to expansion in the model are the availability of capital and natural resources.

Within the capitalist sector available supplies of capital will be combined with labor only up to the point where the marginal product of labor is equal to the going wage. The wage rate in the capitalist sector can best be thought of as being determined by the *average* product per man in the traditional sector plus a margin, although it may also be influenced by conventional views of the minimum required for subsistence, by trade union pressure, or other factors. A substantial fraction of profits will be re-invested so that there will be cumulative expansion of employment in the capitalist sector until the surplus of labor in the traditional sector disappears. Lewis tersely summarizes his two-sector model as follows (*28*, p. 3n):

> Most countries in the early stages of economic development have not one economy but two—a high wage economy (mines, plantations, factories, large-scale transport, etc.) and a low earnings economy (family farms, handicraft workers, domestic servants, petty traders, casual labourers, etc.). As development occurs, labour transfers from the low earnings to the high wage economy. It is of little consequence whether persons moving out of the low earnings economy have been in "disguised unemployment," or whether their marginal product has been zero, negative, or merely small. All that the analysis requires is that the supply willing to move at the current wage rate should greatly exceed the demand.

Clearly, the crucial assumption in this two-sector model is that the rural population is so large relative to the capital and natural resources available that labor shortages and rising labor costs will not be a deterrent to expansion of the capitalist sector. "When capital catches up with labour supply," as Lewis phrases it, the two-sector model is no longer relevant. "Classical economics ceases to apply; we are in the world of neo-classical economics, where all the factors of production are scarce, in the sense that their supply is inelastic" (*28*, p. 26). In reality, of course, the transition is gradual, not abrupt. Existence of a labor surplus in the

traditional sector is a relative concept, and a reduction in the degree to which labor is "surplus" is likely to raise average product per worker in agriculture and real wages in the capitalist sector.

Lewis's two-sector model is obviously akin to the notion of "rural underemployment" or "disguised unemployment." It differs from the extreme version of the disguised unemployment argument in including the proviso that the workers remaining in agriculture could sustain output because they would be able and willing to work harder (*27*, p. 141). It seems to us that this proviso can be further broadened in line with the potentialities that exist for expanding farm output and productivity by methods that make only minimal demands on capital and other scarce resources. That is to say, the validity of the two-sector model does not appear to be seriously impaired if the remaining farm labor force can supply the "required" output by working harder and by introducing technological improvements such as higher-yielding varieties, increased use of fertilizers, and simple improvements in farm implements.

The notion of a "required" increase in farm output is obviously not intended in any rigorous way. Since the price elasticity of demand for "all food" is apparently extremely low, the value productivity of investment for expansion of food crops for domestic consumption will tend to be very high in a situation of scarcity and high prices, but will decline sharply as a result of reduced prices if food supplies increase more rapidly than the expansion of demand. This characteristic of the demand for food also suggests that the magnitude of the effort to enlarge food production should be guided by estimates of the prospective growth of demand. Projections of the growth of aggregate demand for food and for major commodities cannot be made with precision, but useful approximations are possible in the light of prospective changes in population, income levels, and food consumption patterns. Historical experience in other areas and studies of food purchases by income class can throw some light on probable changes in food consumption, although the conclusions can only be suggestive and need to be guided as much by judgment as by statistical analysis.

This is not to suggest that it is either possible or desirable to avoid appreciable fluctuations in the agricultural price level and still larger variations in the prices of individual commodities. Indeed, such variations play an increasingly valuable role in calling forth desirable changes in the composition of farm output and in the intensity of application of agricultural inputs.

Viewing development as a process of cumulative expansion of the capitalist sector and absorption of surplus labor from the traditional sector underscores the significance of the distinction made in section I between resources of high and of low opportunity cost. So long as the conditions of the classical growth model are relevant, factor proportions and productivities will and should be different in the two sectors and a different calculus is applicable to allocation decisions. This is, of course, the rationale underlying the assertion that output and productivity of traditional agriculture should be increased primarily by enhancing the efficiency of labor and other resources that are already present in large quantities and which are difficult to transfer. Hence, the strategic importance of "developmental services" such as agricultural research and extension-type activities that can lead to subtantial increments of output at modest cost—and which

make only limited demands on the resources of high opportunity cost that are required for the expansion of the capitalist sector.

Economic transformation and capital accumulation.—Recognition of the importance of expanding the capitalist sector and transforming the structure of a nation's economy brings into bold relief the exceedingly difficult problem faced by an underdeveloped country in mobilizing the capital required for an "adequate" level of investment. Not only is capital required for the creation and expansion of manufacturing and mining enterprises, but also for overhead investment in transportation, power supply, and communications. Additional needs arise because of the capital and recurrent expenditure required to expand education and other essential governmental services, including the "developmental services" stressed above.

There are, moreover, considerations that argue for a determined and fairly large-scale effort to initiate and sustain growth in the manufacturing sector. Most persuasive are the arguments which apply when there are important external economies because of the high degree of interdependence of some types of industrial activities. Chenery's attempt to give an indication of the quantitative importance of some types of external economies provides a measure of support for the view that in making certain industrial investment decisions it is advantageous to undertake inter-related activities together and on an adequate scale (*6*, p. 114). Hirschman makes a closely related point in emphasizing the desirability of promoting development sequences that have important backward and forward "linkage effects" in the sense that the launching of one enterprise induces decisions to launch related enterprises (*18*, pp. 100–119).

In sharp contrast with the substantial requirements for investment and for expanding the level of government expenditure, the supply of savings and the tax base are small in an underdeveloped economy. The low level of incomes is an important reason for the restricted supply of savings, but the small size of the capitalist sector is probably even more important. Past experience seems to provide substantial support for Lewis's view that re-investment of profits is the chief source of capital formation. Hence a small capitalist sector implies a very low rate of savings and investment. With regard to the small tax base, it is to be noted that heavy taxation of the emerging manufacturing industry is likely to retard the expansion of this important component of the capitalist sector. Indeed, there are frequently cogent reasons for granting tax exemption to certain manufacturing activities because of the special obstacles that confront new industrial enterprises in an economy that has not achieved much progress toward industrialization.

Agriculture as a source of capital.—In an underdeveloped country that is seriously trying to achieve economic progress, the requirements for investible funds and government revenue seem certain to outstrip the supply except in those countries which have large earnings from petroleum or mineral exports or particularly favorable access to foreign capital. The sheer size of the agricultural sector in an underdeveloped economy points to its importance as a potential source of capital for over-all economic growth. During the early stages of economic growth this presumption is particularly strong since re-investment of profits cannot be an important source of capital accumulation when the capitalist sector is only a small segment of the economy. Furthermore, since there is scope

for raising productivity in agriculture by rather moderate capital outlays, the volume of saving and of capital formation financed by the agricultural sector can be increased without reducing the low consumption levels characteristic of the farm population of an underdeveloped country.

Although the possibility exists, political, institutional, and economic problems often make it difficult to translate this increased potential for saving and capital accumulation into an actual increase in invesment. Increased agricultural productivity may be reflected in either (a) reduced agricultural prices, (b) a reduction of agricultural inputs, (c) increased farm receipts, or, most likely, (d) a combination of these effects. This cataloguing of the possible effects of increasing productivity in agriculture suggests the major channels by which agricultural development can facilitate capital formation in the modern or capitalist sector.

It has been suggested above that stable or reduced agricultural prices can facilitate capital accumulation by preventing deterioration or even improving the terms of trade on which the industrial sector obtains food and other agricultural products. In the long run, shrinkage of the farm labor force represents the major agricultural input which falls as productivity rises, but that is a slow process depending on capital accumulation and expansion of the capitalist sector.

Before turning to the possibilities of securing a flow of capital out of agriculture, it is well to consider ways in which the resource requirements of the agricultural sector can be minimized. Emphasis has already been placed on the desirability of developing agriculture by methods that make only minimal demands on resources such as investible funds, foreign exchange, and high-calibre entrepreneurial talent, these being indispensable for expansion of the capitalist sector and therefore of high opportunity cost. Accordingly, it has been argued that priority should be given to raising agricultural productivity by technological improvements promoted by appropriate "developmental services" and by direct, non-monetary investment by farm operators. Likewise, it is desirable for the capital requirements for agricultural expansion, including increased outlays for fertilizers, to be financed as much as possible out of increased farm receipts that may accrue with the increase of productivity and output.

Somewhat less obvious are the possibilities of minimizing tax requirements for education and other services provided for the agricultural sector by means of levying school fees, charges for land registration, etc. Quite apart from the political difficulties that may limit action in this direction, careful judgment is also required to determine those instances in which it is *not* desirable directly to link services rendered with a charge to defray all or part of the cost. For example, in the case of a well established export crop, it may be sound policy to cover part of the cost of research and extension activities related to that crop by levying a tax on the product. But in general, the cost of agricultural research and extension should be borne by general tax revenue. Many farmers are likely not to be able or willing to pay for such services because of insufficient income or insufficient awareness of their value. More basic, however, is the fact that the social returns from increased agricultural productivity are usually much larger than the private benefits that can be appropriated by individual producers since innovations are quickly generalized and much of the benefit redounds to consumers in the form of lower prices.

Historically, land taxes have probably been the major means by which agri-

culture has contributed to the capital requirements for general economic development. In the Soviet Union, however, compulsory collection of grain at artificially low prices was the principal device used to siphon off the increase of output originating in agriculture to facilitate the forced-march development of the nation's industry.[14] In Communist China, the program of organizing the farm population into rural communes seems to be aimed not only at extracting the maximum possible surplus of capital from the countryside, but a maximum labor effort as well. In both instances, drastic reorganization of the farm economy was brought about through coercion supported by an all-pervasive effort to shape individual attitudes and behavior to conform to the national goal of achieving the most rapid possible rate of capital accumulation and increase of gross national product.

In societies that value individual freedom and place limits on the coercive powers of government, the problem is more difficult. It is, therefore, by no means surprising that there has been great variation in the extent to which countries have made use of the opportunity afforded by an increase in agricultural productivity to finance over-all economic development.

Japan is perhaps the clearest example of a country where an increase in agricultural productivity contributed significantly to the financing of economic development. Although Japan of the late 19th and early 20th century was far from being a democratic society, the government of that period was also far from wielding totalitarian powers.[15] Real national income produced in agriculture doubled between the decades 1881–90 and 1911–20, during which time the population gainfully employed in agriculture declined by close to 10 per cent. The growth of total national income was even more rapid, a three-fold increase over the same period. Agriculture contributed over 50 per cent of total national income in the earlier period, close to 40 per cent in the 1911–20 decade, and the increase in income in agriculture accounted for some 35 per cent of the total increase.

The special significance of agriculture's role in relation to capital formation in Japan may be inferred from these additional considerations: (1) as pointed out above, the increase in agricultural output was obtained with very moderate government investments in research, agricultural education, and extension-type activities, and with only a moderate increase in purchased inputs; (2) the improvement in the levels of living of the farm population was substantially less than the increase in agricultural productivity, so that much of the increase in national product originating in agriculture was available for urban consumption and for capital accumulation;[16] and (3) a considerable part of the increase in productivity in agriculture was siphoned off by heavy land taxes and other levies on agriculture that contributed largely to government expenditures to promote industrialization.

[14] See *21*, pp. 508–10, for a brief discussion and citations relative to the Soviet case.

[15] For an excellent analysis of the democratic forces at work in Japan in the decades following the Meiji Restoration, the reasons for their failure, and for the success of the extremist, militaristic groups in the 1930's, see *37*.

[16] This point is clearly at odds with the familiar argument that increased rural incomes resulting from rising farm productivity represents a valuable stimulus to industrial expansion. The latter argument seems most persuasive in relation to products whose manufacture is characterized by economies of scale, so that additional demand is needed to push total demand over a critical threshhold.

Tax statistics show that the land tax accounted for 86 per cent of the tax revenue of the national government in the fiscal year 1875/76, 45 per cent of the tax revenue of the General Account in 1893/94, and 22 per cent of the total tax yield in 1906/07, the tax yield in that year being some seven times higher than the tax revenue of the national government in 1875/76 (*21*, pp. 501–05). Excise taxes and profits of the government's distribution monopolies, which also bore heavily on the farm population, were an increasingly significant source of tax revenue, being more important than the Land Tax after 1900. On the basis of estimates of the division of the total tax burden between agriculture and non-agriculture by Seiji Tsunematsu, it appears that agriculture's share of taxes exceeded 80 per cent as late as 1893–97 and was still above 50 per cent during the years 1913–17 (*20*). The significance of the tax revenues obtained from agriculture is suggested by the active role the Japanese government played in fostering development by constructing "model factories," subsidizing the creation of a merchant marine and shipbuilding industry, and by strategic investment in overhead capital including railroads, education, and research. Some notion of the quantitative importance of government's role in investment is provided by Rosovsky's estimates of investment in Japan. His data indicate that government investment, excluding military investment, rarely fell below 30 per cent of total investment and exceeded 50 per cent throughout the period 1895–1910 (*36*, pp. 354–57).

This heavy reliance on agricultural taxation seems to have been a conscious policy of the Meiji leaders, a policy which the economic historian Takao Tsuchiya has rationalized in these terms: "The urgent necessity of protecting and fostering other industries compelled the government to impose a heavy land tax on the agricultural population to obtain the wherewithal to carry out industrial development programs" (*30*, p. 4).

The role that agriculture has played and is playing in India and Pakistan appears to be strikingly different and gives rise to doubts whether capital accumulation and economic growth will proceed at a "satisfactory" pace. The information available suggests that agriculture's contribution to tax revenue has declined considerably during the postwar period despite the stress that has been placed on promoting economic development. Agriculture has been exempt from general income tax, and the revenue from land taxes has not increased nearly as much as agricultural and other prices. Wald reports that in the seven so-called Part A states in India, land revenues increased only 50 per cent between 1938/39 and 1951/52 while the index of wholesale prices of major agricultural commodities increased 550 per cent during the same period. Land revenues in India provided only 9 per cent of the combined receipts of the central government and states or provinces in 1954, and the comparable figure for Pakistan in 1952 was

On the other hand, if the capital requirements for developing infrastructure and capital goods or export industries are large relative to the amount of capital that can be mobilized, demand is unlikely to be a limiting factor to investment. This condition, we believe, prevailed in Japan during the period 1880–1920, but whether it will be true of a particular nation depends not only on economic factors such as the size of the market, but also on political decisions relative to the pace of development. Developments in Japan during the 1920's suggest that a low level of consumer purchasing power may have been a more important factor limiting expansion of the capitalist sector than lack of investible funds. A tentative examination of the evidence suggests, however, that deflationary policies and an over-valued exchange rate were probably mainly responsible for a marked retardation in the expansion of employment in the capitalist sector in Japan during the years 1920–32 (*20*).

only 5 per cent. In the prewar year 1939 land revenues contributed something over 20 per cent of total tax revenue (*42*, pp. 44n, 54, 61–63).

In certain other countries, the agricultural sector has contributed largely to governmental revenue. Although the yield from the land tax in Burma declined from 40 per cent of total government revenue prewar to 5 per cent in 1952, this was offset by the fact that profits of the state agricultural marketing board have provided about two-fifths of the government's revenue from all sources (*42*, p. 63). Export taxes and allocations from marketing board surpluses have been a major source of development funds in several African countries, particularly Ghana and Uganda.[17]

Although the political difficulties of taxing the agricultural sector are formidable, other obstacles stem from inertia, from some unfortunate characteristics of existing tax schemes, and from a failure to appreciate fully the strategic role that agriculture can and should play in contributing to the capital requirements of economic development. Failure to appreciate agriculture's potential contribution to development is understandable, for in many traditional societies rural taxation was essentially a levy or tribute to support sumptuous living and the construction of monuments by a royal court and nobility. Similarly, a tendency for nationalist leaders to associate land taxation with colonial exploitation has sometimes produced a reaction which led to de-emphasizing or even eliminating taxation of farm land as a significant source of governmental revenue. Indonesia seems to be a conspicuous case in point (*35*, p. 571).

Although many would differ in emphasis, most economists would doubtless agree with Lewis's conclusion that: "The central problem in the theory of economic growth is to understand the process by which a community is converted from being a 5 per cent to a 12 per cent saver—with all the changes in attitudes, institutions and in techniques which accompany this conversion" (*29*, pp. 225–26). Since agriculture in underdeveloped countries typically contributes some 40 to 60 per cent of the national income, the presumption is strong indeed that the transition from a level of saving and investment spelling stagnation to one permitting a tolerable rate of economic growth cannot be achieved unless agriculture makes a significant net contribution to capital formation in the expanding sectors. In his highly provocative analysis of factors bearing on "the pace of development," R. F. Kahn reaches similar conclusions. His answer to the question of political feasibility is one that deserves to be pondered: "Governments are judged not only by their failure to introduce unpopular measures but also by their failure to achieve results. If one is looking at all far ahead it is not timidity which appears to offer a safeguard against political upheaval" (*23*, p. 198).

Population aspects.—One final consideration bears on the importance of struc-

[17] The high tax yields in these instances have been partly a result of inertia in that they have been in considerable measure a consequence of rising world prices and an increase in value rather than physical productivity. This is not the place to discuss the pros and cons of export taxes and marketing board surpluses as devices for stabilization or for mobilizing funds for development. Excessively heavy taxation can, of course, "kill the goose that lays the golden eggs," as Nurkse and others believe to have been true of Argentina's policies during the decade following World War II. Moreover, arguments for mobilizing funds by taxing the agricultural sector are not convincing if they result in spendthrift government policies and large expenditures on "public consumption goods" as Walker and Ehrlich judge to have been the case in Uganda (*43*).

tural transformation as an essential feature of the process of economic growth. Because of the population upsurge that follows the introduction of even a modicum of modern public health measures, it will usually be exceedingly difficult to achieve a substantial increase in per capita incomes unless the sharp decline in death rates is paralleled by a decline in birth rates.

Past experience indicates that structural transformation of an economy together with the accompanying urbanization, increase of incomes, spread of education, and change in attitudes, incentives, and knowledge are necessary conditions for a reduction in birth rates. The possibility exists that direct measures to encourage the reduction of birth rates can be effective in the absence of major changes in the economic and social structure. We are aware of no evidence, however, that provides a basis for believing that such direct measures can by themselves lead to a sufficient reduction of average family size to bring about a leveling off of rapid rates of population growth.[18] Admittedly there are still some underdeveloped countries where sparseness rather than density of population is an obstacle to development. But with the rapid rates of natural increase that have become so common during the period since World War II, there is mounting evidence to suggest that in many countries gains in total output may be absorbed to a large extent in simply maintaining increased numbers with very little improvement in per capita incomes.[19] The historic role of economic and social transformation in contributing to a lowering of birth rates is likely to be highly significant even though its impact may be reinforced and accelerated by more direct measures.

IV. CONCLUSIONS

Something must now be said about the over-simplification involved in the general view of agriculture's contributions to economic growth that has been presented here. The specific resource configuration in a country, or region, obviously has great bearing on its agricultural potential and heavily influences the general priorities as well as the details of development.

Since Professor Lewis's version of the classical growth model has been invoked to clarify some of the inter-relationships between agricultural and industrial development, a crucial question is the extent to which the propositions advanced are relevant only to countries with dense rural populations. The nature and extent of the modifications in the two-sector analysis that would be called for in the case of the sparsely populated regions of tropical Africa and South America

[18] Japan's experience is of interest in this regard. Crude birth rates declined slowly from 36.1 per 1,000 in 1920 to 32.4 in 1930 and 29.4 in 1940. Between 1950 and 1955 there was an abrupt decline in the birth rate from 28.1 to 19.3, a decline that seems to have been influenced substantially by widespread resort to abortion which was legalized by the Eugenics Protection Law which became effective in 1949 (*41*, pp. 269, 311). Since Japan had already witnessed substantial economic and social transformation by 1920, these changes are not particularly relevant to the situation in presently underdeveloped countries. More pertinent to the possible effectiveness of direct measures in rural areas is an experiment carried out by a group of doctors in three Japanese villages. Education to overcome the traditional "Kodakara" concept (that children are the greatest wealth of a family and of a country) and provision of information concerning contraceptive methods (and free contraceptive supplies) led to a decline in the birth rate in these villages from 29.6 to 14.6 per thousand in the third year and 13.6 in the seventh year (*25*).

[19] The study by Coale and Hoover of *Population Growth and Economic Development in Low-Income Countries* (*8*) presents a careful and persuasive argument that continuation of present high fertility rates in India will significantly restrict the gains in per capita income that are likely to be attained.

do not seem to have been worked out; and we have not undertaken that task in this paper. It is obvious that mechanization will tend to become economic at an earlier stage if there is a scarcity of labor in the countryside. Whether a relatively sparse rural population will in fact result in inadequate agricultural output or labor shortages and rising wages that deter expansion of the capitalist sector will depend on many factors. Clearly, one crucial factor is the rate of capital formation and expansion of employment in the non-agricultural sectors. Another is the rate of population growth which will influence both the demand for farm output and the supply of labor forthcoming for agriculture and industry. Highly pertinent also are the prospects for developing production of profitable export crops. If land is abundant and there is good potential for enlarging output of export crops, the assumption of surplus labor in agriculture would appear to be highly inappropriate. In British East Africa, for example, recruitment of labor for work on plantations or in industry is commonly alleged to be difficult by those who undertake it.

It is also well to recall that many of the presently underdeveloped countries face special problems because of the limited understanding of the problems of technological improvement with tropical soil and climatic conditions. Extensive research has been carried out with respect to a limited range of commercial export crops, but relatively little attention has been given to the basic food crops. This problem is conspicuously important in tropical Africa where answers are yet to be found for many of the technical and economic problems of developing more productive farming systems as an alternative to the traditional shifting cultivation. There are even indications that in some areas unresolved technical problems in the use of mechanical equipment under tropical conditions is a more important obstacle to mechanization than the economic questions of availability and allocation of funds for the purchase of machinery.

Despite these and other qualifications, we believe that the analysis offered here of the nature of agriculture's contributions to economic development has considerable relevance even for underdeveloped areas where the rural population is fairly sparse. The analysis would have suggested, for example, that large-scale settlement and mechanization schemes such as the Niger Agricultural Project at Mokwa in Nigeria, aimed primarily at increased production of local food crops, represented a highly questionable use of scarce resources. The failure of such projects is not surprising. On the other hand, the notable success of the Gezira Scheme in the Sudan is not hard to explain. The scheme was oriented toward the production of a high-value export crop, long-staple cotton. The Gezira lies in an arid zone where crop production is risky and yields meagre without large-scale irrigation facilities; alternative approaches to agricultural development and other productive employment for the labor force drawn to the scheme were largely ruled out by technical considerations.[20]

Of the wide relevance of certain of the conclusions that have been suggested there can be little doubt. Failure to pay proper heed to increasing agricultural output and productivity is likely to jeopardize over-all economic development. Even though the distinction between resources of high and low opportunity cost

[20] For authoritative discussions of the two projects mentioned see *1* and *16*.

may be less applicable in areas of sparse rural population, it remains advantageous to realize the potential that exists for enhancing the productivity of the existing agricultural industry by technological innovations. This in turn points up the high returns obtainable from intelligent efforts to strengthen "developmental services" such as agricultural research and extension programs, particularly when these are combined with increases in conventional inputs such as fertilizers and insecticides. Finally, the proposition that a "satisfactory" rate of growth depends on agriculture making a net contribution to the capital requirements for industrial expansion would appear to apply to most late-developing economies.

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